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## THE WHITE RAT AND THE MAZE PROBLEM: III. THE INTRODUCTION OF A TACTUAL CONTROL

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In two papers, appearing in preceding numbers of this Journal, I have attempted to show that vision and olfaction can be introduced as controls into the maze problem and to demonstrate some of the effects of such an introduction upon the learning process of the white rat. In this article I wish to review, briefly, in the light of the previous discussions, some work on the maze problem where the conditions for tactual and cutaneous control were emphasized and to add some experimentation not previously reported. For the full details of the earlier work see my monograph, "The Function of the Vibrissae in the Behavior of the White Rat."<sup>1</sup>

While this paper, the third of a series, attempts to show how tactual elements enter into and modify the maze reactions, it must be understood that the sensory experience is always a complex. Yerkes has sounded the warning clearly when he says: "An animal responds to a situation, not to any one independent and isolated stimulus. Every situation, to be sure, may be analyzed into its component simple stimuli, but the influence of each is conditioned by the situation."<sup>2</sup> The difficulty of isolating the tactual element is the chief reason why there has been so little work done with it in studies of labyrinth

<sup>1</sup> Vincent, S. B. The Function of the Vibrissae in the Behavior of the White Rat. *Behavior Mon.*, vol. 1, no. 5.

<sup>2</sup> Yerkes, R. M. Relations of Stimuli in the Frog. *Harvard Studies*, vol. 2, p. 546.

learning. The experimentation which has been undertaken up to this time has consisted mainly in moving the labyrinth to a different base, covering the floor path with different substances, interposing hurdles, and the use of anesthetics on the feet of the animals.

Opinions as to the value of the sense in such problems have been based upon observation and voiced in general statements like this: "The longer one observes the behavior of the dancing mouse the more he comes to believe in the importance of touch and motor tendencies."<sup>3</sup> Or the assumption was perhaps a specific one and yet unsupported by any evidence, as: "Tactual-motor sensations furnish the essential data for the recognition and discrimination involved in forming the special associations at critical points."<sup>4</sup> One investigator has made apparently contradictory statements, as: "The indications point to the fact that the rat in no way uses his cutaneous sensations as a basis for 'sensing' the correct turns in the maze as distinguished from the incorrect."<sup>5</sup> In this case the feet of the animal were anaesthetized with ethyl chloride. Reporting some experiments with blind animals he said: "Runs squarely down the middle of the galleries, makes his turns into the various entries as boldly and with as much sureness as do the normal rats. The vibrissae undoubtedly play a large part (though not an indispensable one) in the early reactions of these rats to the maze."<sup>6</sup> Of normal animals he remarks: "In all probability the rat does not discriminate his turns by means of any data contributed by the vibrissae." "Vibrissae undoubtedly warn him of the presence of solid objects. . . . The function of the vibrissae to some extent at least may be dispensed with once the path is learned."<sup>7</sup> These seeming contradictions, however, are due to the confusion in the report of those activities involved in the formation of the habit and those essential to its control when established. The conclusions are those drawn from one type of maze and one form of motor habit and while possibly valid in this particular problem cannot be carried over to all such co-ordinations.

<sup>3</sup> Ibid, Dancing Mouse, p. 178.

<sup>4</sup> Small, W. S. Mental Processes of the Rat. *Amer. Jour. Psy.*, vol. 12, p. 237.

<sup>5</sup> Watson, J. B. Kinaesthetic and Organic Sensations. *Psy. Rev. Mon. Sup.*, vol. 8, no. 2, p. 78.

<sup>6</sup> Ibid, p. 58.

<sup>7</sup> Ibid, p. 69.

Miss Richardson makes some definite statements though not in connection with labyrinth problems: "Slight contact (with plane) seemed to give her immediate orientation."<sup>8</sup> "The basis seemed to be that afforded by touch. Contact with the plane was doubtless evidence of its presence." . . . "It was only when they came in contact with the plane that some sensory impulse connected with its fall set off the old association and they would dash to the door of the box."<sup>9</sup> "There was no indication that any of the rats located the door by means of vision for each rat passed the door while 'searching' for it without reaching to it. Yet when the door was touched there followed the examination of the latch and the requisite movements to open the door." . . . "Locating the door as before probably with the snout."<sup>10</sup> "The normal rats like the blind rats seemed to discover the latch by contact."<sup>11</sup>

A layman would scarcely question the importance of the tactual experience in the life of animals, yet in experimental work its function had been called in question even in such problems as Miss Richardson mentions and kinaesthesia had barred all rival contestants in labyrinth learning. It was in order to test the control in the maze that this work was undertaken.

#### DESCRIPTION OF MAZE

The method used in testing this tactual control was not quite the same as that employed in the work with vision and olfaction. In those experiments the stimulating values of the true path and the blind alleys were made to differ in as pronounced a manner as possible. In this case there was no attempt made either to accentuate the contact values of the floor or walls of the maze or to offer contrasting standards in the true path and the false. Another maze was built on a new plan where the conditions, it was hoped, were such that not only could the tactual functioning of feet and vibrissae be seen but also that such functioning would be a necessary part of the learning process. (Figure 1.)

<sup>8</sup> Richardson, Florence. A Study of Sensory Control in the Rat. *Psy. Rev. Mon. Sup.*, vol. 12, no. 1, p. 39.

<sup>9</sup> *Ibid.*, p. 40.

<sup>10</sup> *Ibid.*, p. 55.

<sup>11</sup> *Ibid.*, p. 56.



The runways to this maze had sides which could be detached. When this was done there was left a maze pattern of open, elevated paths but these paths had sufficient space between them so that the animals did not try to jump from one to the other. It was found that on this open maze, where the whole pattern was exposed, the visual control was not sufficient to prevent there being just as real a problem as was seen in mazes with enclosed sides. The situation forced the use of the feet and the vibrissae in a way that the other mazes did not and this fact accounts for the title at the head of this paper. Other sensory elements contributed to the learning, without doubt,

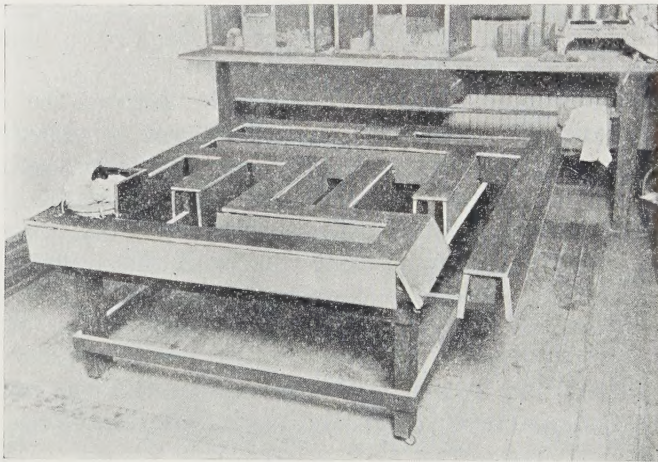


Fig. 1—The maze as used with sides down

but the tactual-cutaneous factors were the prominent ones and the ones which we wished to throw into relief. As it is desired to compare the results obtained in this work with those secured where vision and olfaction were emphasized in the Hampton Court maze, let us compare the two labyrinths.

#### COMPARISON OF HAMPTON COURT AND X MAZES

The length of the true path in the Hampton Court maze is 40 feet, in this 17 feet. There is one more blind alley in the H.C. maze than in this. The *cul de sacs* have a total length

of 30 feet in the one and 9 feet in the other. The paths, both true and false, of the H.C. maze are more complex in nature. The results obtained from the H.C. maze and those given by the smaller maze, which we will call the X maze, when the sides are on are very similar. In table 1 they are given in tabular form together with the dimensions of each maze.

To make these results comparable it is necessary to multiply the errors of the X maze by  $7/6$ , since the H.C. maze has 7 errors while the X maze has only 6. The time taken to run the maze should be directly proportional to the length of the path. In the first trial in any maze the *cul de sacs* are explored rather thoroughly; therefore the time of the first trial in the X maze should be multiplied by  $40/17 \times 30/9$ , the ratios between the lengths of the true paths and the *cul de sacs* in the two mazes. In the final trials, however, the errors are cut out and to get the comparative speed we multiply the figures for the X maze by  $40/17$  to correct the speed for the true path. By comparing the corrected results of the X maze with those of the H.C. maze we can see that the statement of similarity is substantiated.

The X maze took an average of four more trials to learn than the H.C. maze. The slower learning time for the X maze is doubtless a result of the character of the *cul de sacs*. There are three pairs of blind alleys in this maze. One and three are exactly of the same length and character and so are two and six and likewise four and five. The two latter pairs differ only four inches in length while after the turns the distances in 1, 2, 3 and 5 are identical. (See figure 1.) The distances on the true path between the turns are also comparable. If, after the habit is formed, the running under these conditions is carried on largely in kinaesthetic terms, as we believe, then differences between the kinaesthetic elements in the series should favor such an accomplishment. Such differences in kinaesthetic elements are differences in complexity, differences in the distances between the turns as well as in the direction of the turns, and differences in the lengths of the *cul de sacs*, etc. Too great a similarity between such kinaesthetic units would hinder the learning. The plan of the H.C. maze, according to this conception, is more favorable for learning and hence the slower learning time of the X maze. The corrected figures for the X maze show a greater average number of errors in the first



trial and in the last five trials but looking at the average number of errors for the first five trials and the total errors per animal we see that the balance is in favor of X maze.

Thus the error balance in the figures of the two mazes now leans to one side and now to the other. These differences, also, probably spring from the form and character of the *cul de sacs*.

The lower final speed in the X maze is caused by one slow animal. If we take the time for all of the runs in which there were no errors in both series and from these records compute the speed per foot for each maze we find it to be exactly the same, 2.5 feet per second. This is not the final speed, however.

The object here is not to go over these details item by item but merely to show that, in general, these mazes are alike in type and the reactions made in them are therefore approximate.

#### COMPARISON OF EXPERIMENTS ON X AND Y MAZES

We will now turn to a consideration of the experimentation on the X maze, where the sides to the runways were on, and the same maze, which we will call the Y maze, the open maze, where the runways had no sides.

The behavior in the X maze needs no description but that in the Y maze showed essential differences. When the sides were taken from the runways and the rats put on the maze they showed a marked tendency to follow the edges of the paths. They did this either by turning their vibrissae down against the sides or by curling their toes over the edges of the board. That this was a real control was shown by using rats whose vibrissae had been cut on one or both sides of the head, by using blind rats with and without vibrissae and rats in which the branch of the fifth nerve which innervates the upper lip and snout had been cut. The learning in all of these cases was made more difficult except in one instance. In this case the vibrissae were cut on one side only. As a result, the animals were forced to keep to one side of the maze and by following this side they made their way around the labyrinth almost immediately. It is impossible here to go into all of the evidence and readers are referred to the original monograph.<sup>12</sup> The work conclusively showed that the tactual-cutaneous experience had

<sup>12</sup> Op. cit.

a vital part in the solution of the problem. In the end the rats ran this maze with as much boldness and confidence as the other, with heads up, almost leaping corners, etc. The one exception was the group of blind rats without vibrissae.

Let us compare the results of the two mazes as to accuracy and speed. We find that the time of learning was the same but in the Y maze the errors were less by one-half in the first trial and one-third in the first five trials, and the total number of errors was decreased about one-third although the final accuracy of the two mazes was practically the same. The beginning time was shorter because of the fewer errors but the average time of the first five trials was about the same in both. The final speed in the Y maze was slightly better. The most noticeable difference, then, was the decrease in errors. The open maze, from the beginning, favored accuracy and it should be noted that this accuracy was not attained at the expense of speed.

In a maze, where the paths are enclosed by restraining walls, there is little need of fine bodily adjustments. The turns in the H.C. maze and in this maze are always 90 degrees but the place of the turn in the H.C. maze is always marked by some corner or projecting wall against which the body of the rat brushes or his vibrissae drag as he runs. A railway engineer does not have to keep his train on a straight course by the fraction of an inch, he has only to develop speed, his track is laid for him. The analogy is not perfect but in the enclosed maze the rat is comparatively "safe." He does not have to control, as on the open maze, the finer postural and positional adjustments and as a result of this looseness of running he makes more errors. On the open maze the control of these finer adjustments is necessary in order to avoid slips and falls and hence there is greater initial and final accuracy.

The nose, feet and vibrissae were constantly used at the different places of turning. The direction of the turn seemed a much easier thing to conquer than the exact place. The operated animals were at a great disadvantage. Vision aided these finer adjustments but the nose and feet and vibrissae seemed to be of greater help to the rat than sight. However, either sight or the touch of nose or vibrissae seemed to be a vital necessity to the learning. The animals could not well dispense with both in such a problem as was here presented.

## THE X MAZE RE-LEARNED AS THE Y MAZE

That the habits set up in the two mazes were inherently of different type was shown by the following experiment: After the group of animals whose records are given for the X maze in table 1 had learned the maze the sides were removed and the rats were tried again. Kinaesthesia had apparently been firmly established during the first experiment and while some disturbance was to be expected, it was thought that it might affect the runs of but one day. The outcome shows the danger of supposing anything about animals. These rats had to relearn the maze almost as if it were a new problem. The old habits did not meet the situation. The animals went out upon the maze with flattened, crawling bodies; they clung to the edges with their toes, they followed these edges with their vibrissae; they used apparently every tactual-cutaneous help possible. While the fewer initial and total errors seem rather good evidence that something was carried over from one maze to the other, the fact that it took over eleven trials on an average for the relearning, as well as the evidence of the observed behavior, indicates that the habit had to be re-established through new sensory aids. A summary of the numerical data may be seen in the last column of table 1.

The maze pattern was the same. The kinaesthetic series was the same: the distances, turns, all that goes to form what Professor Watson calls a kinaesthetic element, but the other sensory elements, always present in the kinaesthetic complex, light, possibly odor and sound but chiefly touch had greatly changed. Always, as the rat ran in the X maze, his sides and vibrissae brushed the walls, the projecting partitions and the angles of the box. All at once this part of the sensory experience was gone. It could be and it was replaced but with a tactual experience of another sort requiring very different adjustments. In addition there was the necessity for the finer adjustments previously mentioned. Thus the problem became a new one. The position which I desire to maintain here and upon which I desire to lay emphasis is that, while in a fully formed habit kinaesthesia probably predominates as a control, the sensory experience is never purely kinaesthesia but always a complex and the finer are the adjustments which need to be made the more necessary the associated sense qualities of vision and touch become.



TABLE 1  
COMPARISON OF MAZES—DIMENSIONS, RECORDS

	Hampton Court Maze	X Maze	Y Maze	X Maze Corrected	X Maze re-learned as Y Maze
Total length of true path...	49 ft.	17 ft.			
Length of <i>cul de sacs</i> .....	30 ft.	9 ft.			
Number of <i>cul de sacs</i> .....	17	8			
Number of turns, true path.	19	7			
Time of learning.....	12.1 ± 3.6 trial	16.5 ± 3.7 trial	16.5 ± 6.6 trial		11.8 ± 9.2 trial
Average errors first trial....	14.7 ± 7.7	18 ± 8.8	9.5 ± 4.05	(x 7/6) 21	4.6 ± 1.3
Average errors first five trials.....	48.7 ± 17.7	30 ± 12.8	21 ± 5.2	" 35	11.4 ± 3.3
Average errors last five trials.....	1 ± .14	.18 ± 2.7	.09 ± .11	" .42	0.
Total average errors per animal.....	66.6 ± 16	51 ± 23	37.3 ± 5.1	" 59	22 ± 7.6
Time first trial.....		7.2 ± 3.8	5.1 ± 2.5		2.9 ± 1.2
Average time first five trials.	16.3 ± 6.7 min.	1.8 ± 2.7 min.	1.9 ± .7 min.	(x 40/17 x 30/9) 14.1 min.	1.19 ± .4 min.
Speed last five trials.....	.31 ± .05 min.	.18 ± .06 min.	.15 ± .03 min.	(40/17) .42 min.	.1 ± .01 min.
Average speed in trials without error.....	2.5 ft. per sec.	2.5 ft. per sec.	1.8 ft. per sec.		1.8 ft. per sec.
Total surplus time.....	93.9 min.	15.3 ± 6 min.	13.9 ± 4.3 min.		8.93 ± 2.38 min.

## CONCLUSIONS

The conclusions from this study are that, given conditions which favor or necessitate the use of vibrissae or the tactual use of nose or feet, the maze habit is not more quickly established but that during the setting up of the habit fewer errors are made and because of this the time per trial is lessened and time is gained. The conclusion is also drawn that these conditions make, within the limits of the experiments, for greater final speed as well as for greater final accuracy.

# A STUDY OF THE BEHAVIOR OF THE PIG *SUS SCROFA* BY THE MULTIPLE CHOICE METHOD

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## INTRODUCTION

The multiple choice method of studying ideational and allied forms of behavior was first briefly described in a lecture on the study of human behavior delivered at Cold Spring Harbor in 1913.<sup>1</sup> It has recently been more fully described in a paper which presents the results of its application in the study of the crow.<sup>2</sup> We shall, in the present report, assume knowledge of the previous descriptions and state only the essential features of the method and its adaptation to the organism observed.

It was devised in the Psychopathic Hospital, Boston, as a means of obtaining comparable records of the ideational behavior of mentally deficient and deranged individuals. But it was also hoped that it might prove widely serviceable as a comparative method for the study of various types of organism.

In many of its essential features, the Yerkes multiple choice method is similar to the Hamilton quadruple choice method,<sup>3</sup> but whereas in the latter four reaction-mechanisms are employed and only problems which, strictly speaking, are insoluble are presented to the subject, the present method involves the use of a variable number of reaction-mechanisms and the presentation of soluble problems of a wide range of difficulty.

The experimenter seeks, in using the multiple choice method, to present to his subject, no matter what its type, age, or condition, a problem which may be solved by the perception of a

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<sup>1</sup> Yerkes, Robert M. The study of human behavior. *Science*, 1914, **39**, pp. 625-633.

<sup>2</sup> Coburn, Charles A. and Yerkes, Robert M. A study of the behavior of the crow *Corvus Americanus* Aud. by the multiple choice method. *Journal of Animal Behavior*, 1915, **5**, pp. 75-114.

<sup>3</sup> Hamilton, G. V. A study of trial and error reactions in mammals. *Journal of Animal Behavior*, 1911, **1**, pp. 33-66.



certain constant relation or group of relations within the reaction-mechanisms. For example, the mechanism to be operated may, in the case of one problem, be the middle one of the group, and the total number of mechanisms presented may vary from three to nine. Only by perceiving and appropriately responding to the relation which the experimenter designates as middleness, can the subject solve the problem.

It is necessary only, in the presentation of a varied series of multiple choice problems to a given subject, for the experimenter to devise a type of reaction-mechanism which is appropriate to the action-system of the organism to be observed. We have thus far made use of a simple keyboard for human subjects, while for crows, ring-doves, and rats, we have employed a series of similar boxes, each with entrance and exit doors which can be operated at a distance by the experimenter. The form of device which has proved suitable for the study of pigs will be described in this report.

It has proved very easy to develop suitable mechanisms and we have every reason to suppose that this new method has great advantages over most others for the comparative study of behavior in that essentially the same problems may be presented to extremely different types of subject.

The method has been employed in experiments with normal and defective children, normal and insane adults, pigs, rats, crows, and ring-doves.<sup>4</sup> To all of these subjects, four problems have been presented. They may be described briefly, by definition of the correct reaction-mechanism, as Problem 1, the first mechanism at the subject's right; problem 2, the second mechanism at the subject's left (that is, from the end of the series at the subject's left); problem 3, alternately the first mechanism at the subject's right and the first at its left; problem 4, the middle mechanism of the series.

It has become increasingly clear, as our investigations progressed, that the perfect solution of a problem by a given subject is of much less importance as a matter of record than is detailed information concerning the types of reaction and the appearance and disappearance of reactive tendencies during the course of experimentation. For the solution of a problem means simply

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<sup>4</sup> The results of our experiments, except in the case of the crow, have not been published.

the termination of a series of observations. It is essential, therefore, that the experimenter fix his attention rather on the immediate response of his subject than on the attainment of the solution of problems. We especially call attention to this matter because many experimenters seem to feel dissatisfied with other than speedy and completely positive results. It seems fair to insist that by the multiple choice method positive results are obtained even if a subject cannot solve any of the problems which are presented to it.

Since it is our intention to more fully discuss the essential features and the technique of the multiple choice method elsewhere, we shall here content ourselves with these brief introductory statements and references. It should perhaps be added that only by reading the earlier article on the behavior of the crow can the reader hope to fully understand the present report.

#### SUBJECTS

The subjects of the experiments which constitute the observational basis for this paper were two Chester white pigs. They were born April 1st, 1914, and they were therefore two months old when, on June 2nd, they were taken to the Field Station from an adjoining farm and placed in the experimental situation. We shall refer to these individuals as the male and the female, since both sexes were represented. The male, however, had been castrated before we obtained the animals.

From the first, individual differences were conspicuous. The male was considerably smaller and less active and energetic than the female; he ate less and showed less initiative. Throughout the period of observation, both animals were in perfect health and at no time was there reason to suppose that either environmental or physiological conditions were unfavorable to our experiments.

From birth these pigs lived practically out of doors, having a yard to run in and a rather open shelter from storm.

Although the experimenters had expected much of the pigs because of the indications from casual observation of their behavior, it may be said at once that they proved far more satisfactory subjects than we had dared to hope. Indeed, they worked so steadily and uniformly through the investigation that there was practically no loss of time. It is chiefly because of

this unexpectedly favorable relation of subject to method that we were enabled to obtain, during the summer of 1914, the numerous results reported below.

#### APPARATUS

Fortunately, it was possible at the Franklin Field-Station to locate our apparatus in an orchard convenient to the buildings. A rough shelter was built for the pigs under a large apple tree, and convenient yards were arranged by the appropriate use of wire fencing.

The accompanying figures give a fairly good idea of the experimental situation. In figure 1 A, the multiple choice apparatus appears in the foreground, behind a fence which completely surrounds the enclosure. Immediately in front of the apparatus is a bench for the observer. Systems of weighted cords, conspicuous in 1 A, enable the experimenter to operate the slide doors of the multiple choice boxes.

The arrangement of the yards is made clear by figure 1B and figure 2. It was necessary to be able to isolate the pigs for observation as well as to have the apparatus so arranged that an individual could readily be admitted for a trial and on the completion of its reaction, be returned to its appropriate yard.

The multiple choice apparatus proper consists of nine similar boxes, shown in ground plan in figure 2. They were built of rough boards and numbered conspicuously 1 to 9. Each box is sixty inches long, by twenty inches wide, by forty-eight inches deep, with a slide door at each end. The distance between these doors on the inside of the box is forty-eight inches.

From each of the entrance and exit doors a woven window-weight cord extends upward, through a pulley, then horizontally forward through another pulley, and downward, ending in a weight nearly over the observer's bench. To all of the cords from the entrance doors, white weights were attached; to all from exit doors, black weights. Each weight was sufficient to hold its door in position after the latter had been raised. It was found that this required about ten pounds, and iron window weights served our purpose.

In front of the exit door of each box is a v-shaped food trough which is divided into nine like parts by the partitions between



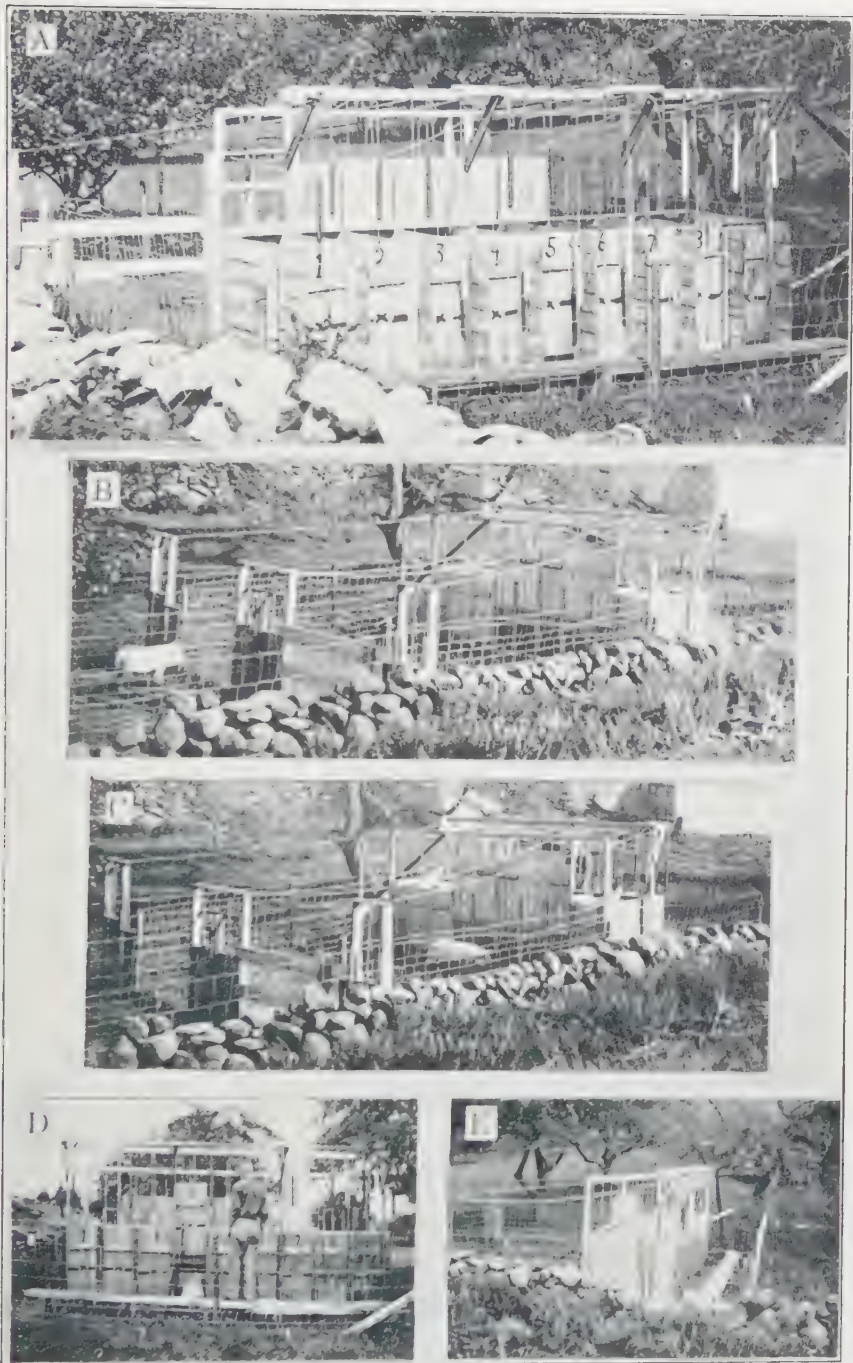


FIGURE 1. Multiple Choice Apparatus for Use with Pigs

A. The reaction-mechanisms from the experimenter's position, showing weighted cords for operating doors. Entrance doors 2 to 6 are raised.

B. The same from the pig's point of view, showing one pig waiting in yard for trial. Entrance doors 2 to 6 raised as in figure A.

C. The same view as that of figure B except that the pig has been admitted to the reaction-space and is about to enter the middle box (no. 4) of those whose doors are open.

D. Here the pig is shown, after appropriate reaction, feeding in the trough of box no. 4. The experimenter appears in the position necessary for manipulation of cords and observation of response.

E. The reaction-mechanisms seen from one end.



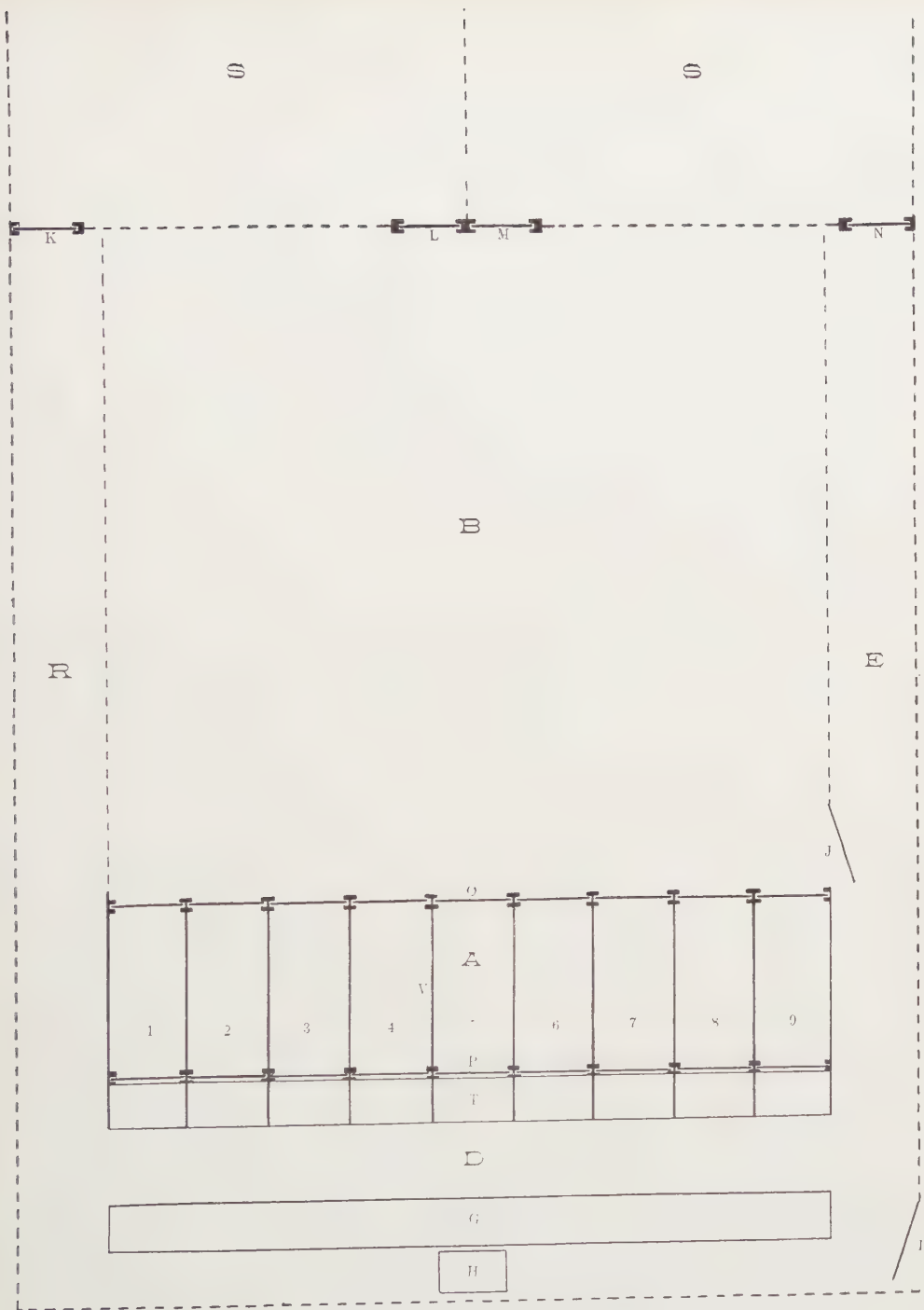


FIGURE 2. Ground Plan of Multiple Choice Apparatus Used for Figs. Scale  $\frac{1}{48}$

A, reaction mechanisms, nine similar boxes or stalls; V, stall number 4; O, entrance door of box; P, exit door of box; T, food trough of box; G, observer's stand and H, writing table; D, runway between trough, T, and stand; G, S, S, yards; B, reaction space; R, E, alleys or runways connecting D with S; I, observer's entrance door to apparatus; J, observer's entrance door to reaction space B; L, M, slide doors between yards and reaction space; K, N, slide doors between yards and alleys.

The weighted cord systems for operating the entrance and exit doors (twenty in all) are not shown in this figure. They may be seen in figure 1, A, B, and C.



## PROBLEM 4. Middle Mechanism of the Series

Setting	Doors open	No. of doors open	No. of right door
1.....	2. 3. 4.....	3.....	3.....
2.....	5. 6. 7. 8. 9.....	5.....	7.....
3.....	1. 2. 3. 4. 5. 6. 7.....	7.....	4.....
4.....	7. 8. 9.....	3.....	8.....
5.....	4. 5. 6. 7. 8.....	5.....	6.....
6.....	1. 2. 3. 4. 5. 6. 7. 8. 9.....	9.....	5.....
7.....	1. 2. 3.....	3.....	2.....
8.....	2. 3. 4. 5. 6.....	5.....	4.....
9.....	3. 4. 5. 6. 7. 8. 9.....	7.....	6.....
10.....	6. 7. 8.....	3.....	7.....
		Total	50

Both punishment and reward were used in these experiments. The punishment consisted of confinement for a definite interval, usually one minute, in each wrong box entered, while the reward consisted of food which could be obtained in the trough of the right box.

## EXPERIMENTAL PROCEDURE

We shall now briefly enumerate, in order to supplement the descriptions of apparatus and methods which have been given, the steps in a regular series of observations.

The experimenter having entered the enclosure with a supply of food, record-book, stop-watch, etc., first raises each of the nine exit doors and places in each section of the trough a quantity of food (sour milk, shelled corn, vegetables). He then lowers the exit doors, thus covering the food, and takes his position on the observation bench. In case both pigs are in the shelter yard, it is next necessary for him to drive one of them into the other yard. This having been done, he may proceed to set the entrance doors for the first trial. Let us suppose that the problem to be presented is problem 1 and that setting 1 is first to be used. In this case the experimenter raises entrance doors 1, 2, and 3. He is now ready to admit one of the pigs to the reaction space B of figure 2. This he does by raising momentarily the appropriate slide door between B and S.

The instant the pig enters the reaction space, the experimenter starts his stop-watch and begins to record the important features of the behavior of the animal, noting especially its approach to the several doors, its tendency to enter boxes and the actual entrance and time of entrance into any one of the three acces-

sible boxes. Let us suppose that the animal enters directly box 3. Immediately the experimenter lowers the entrance door and thus confines the animal in the small compartment as punishment for an incorrect choice. At the expiration of one minute, the entrance door is raised and the pig is allowed to retreat from the box and make another choice. We may now suppose that the animal, after passing in front of boxes 2 and 1, returns to 1 and enters it. The experimenter immediately stops his stop-watch, lowers the entrance door, and, since this box is by definition the right one, he immediately raises the exit door and rewards the animal for correct choice by allowing it to eat for a few seconds. He then, either by speaking to the pig or by touching it with a whip, induces it to pass from the box by way of the passage, D, and the alley, R or E, back to the appropriate yard, S.

Having reset the apparatus, the experimenter now gives the other pig a trial with the same problem and either with the same or with a different setting of the doors.

As a rule, the animals were fed only in the trough of the apparatus. They were almost always hungry, and although sufficiently well fed to keep them growing and in excellent health, they usually seemed fairly hungry at the end of a day's work. In no case was it necessary, in order to induce them to work steadily, to have them extremely hungry.

The influence of visual and olfactory factors was to be expected, and at various points in the investigation, precautions had to be taken against following.

#### PRELIMINARY TRAINING

On June 2nd the pigs were brought to the Field Station and placed in the shelter yard, and in the afternoon of the same day, they were fed in the trough of the apparatus, all of the doors of the boxes and the yards being raised.

During the next six days they became thoroughly accustomed to the apparatus and learned both to feed in the trough and to make the trip readily from the yards, through the apparatus, and back to the starting point. They very quickly and satisfactorily adapted themselves to the situation, while at the same time becoming thoroughly tame and indifferent to the presence of the experimenter.

On June 9th it seemed fitting to attempt a series of preliminary trials. Each animal was given, in turn, opportunity to secure food in each of the nine boxes. When the subject entered the reaction space, B, the entrance door of a certain box stood open, and as soon as the animal had entered that box, the experimenter closed the door behind it and opened the exit door in front of it, thus enabling it to obtain food. During these preliminary trials, the pigs were in separate yards and were given their trials alternately.

We shall now report the results of our regular experiments.

#### RESULTS OF EXPERIMENTS

As it is essential to present the data for each trial in the series of experiments, tables 1, 3, 4, 6, 7, 9, and 10 have been constructed after the following manner. At the head of each table stand the several settings, the letter S serving as an abbreviation for setting and the number following it designating the place of the setting in the series. Immediately under the number of the setting appear the numbers of the doors open with the one to be chosen (correct one) printed in bold face type. Below this preliminary information concerning the particular problem in question, appear the results for each of the trials of each subject. The column headed T gives the number of a trial in the total series of trials for a given subject, in a given problem. Following the number of the trial are the numbers of the boxes entered, in the order of entrance. Referring to table 1, we discover that the female in her first trial under problem 1 selected, of the three boxes whose doors were open, first, number 3. She was, of course, punished by being confined in this box for one minute, and on release entered box 1, which was the correct box, and received the reward of food. Or again, in table 3 it may be noted that in trial 146, under problem 2, the female entered, in order, boxes 7, 9, 7, and 8, the group of open doors including 7, 8, and 9, and the box to be entered being number 8.

These tables will enable the reader to obtain quickly definite information concerning the forms of response and the changes therein during the course of experimentation. We shall present the several tables under the problem numbers and reserve further comment for the section on the discussion of results.



## DISCUSSION OF RESULTS

The results will now be discussed under the headings of the four problems, and in connection with each a condensed tabular summary of the experiments will be offered, together with such comments as are necessary on the experimental procedure, the behavior of the subjects, and the significance of the various forms of response.

## PROBLEM 1

This problem, for which the definition of the correct mechanism is the first at the subject's right, proved extremely easy for the pigs. Incorrect choices were surprisingly few, and the number of trials necessary for the perfect solution of the problem was also surprisingly few for both subjects, the female having chosen correctly throughout a series of ten settings at the end of forty trials and the male having similarly succeeded at the end of forty-five trials.

As is indicated by tables 1 and 2, which contain all of the data for this problem, the experiments were not discontinued at this point, but each individual was given additional opportunity to work out the problem. In the light of our later experience, this was a mistake, but at the time we were unconvinced that the animals were depending upon the relation of the correct mechanism to the other members of the group, and we proceeded further with our observations in order to settle certain points which were in doubt.

From the first it was evident in connection with this problem that the female was more intelligent than the male, and that he tended to be markedly influenced by her. After observations were discontinued with her on June 14th, he reacted very poorly for a number of series, and then again improved and reacted perfectly in the last three series given on June 15th.

In this problem the total number of doors open in the ten settings was, as may be seen by reference to the data presented on page 191, thirty-five. Of these, ten were of course correct. Hence the probability of a correct first choice apart from experience would be 1 to 2.5. In table 2, it appears from the data of the last column for each individual that the ratio of correct to incorrect first choices was on the first day of training 1 to 1 for the female and 1 to 2.33 for the male. It should here be stated that in table 2, as well as in the like tables for the other



TABLE 2  
DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
FIRST CHOICES  
PROBLEM 1

Female							Male						
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
June 10	1- 5	3	2				June 10	1- 5	2	3			
"	6-10	2	3	5	5	1:1	"	6-10	1	4	3	7	1:2.33
11	11-15	1	1				11	11-15	2	3			
"	16-20	5	0				"	16-20	2	3			
"	21-25	4	1	13	2	1: .15	"	21-25	2	3	6	9	1:1.50
12	26-30	4	1				12	26-30	4	1			
"	31-35	5	0				"	31-35	3	2			
"	36-40	5	0				"	36-40	5	0			
"	41-45	4	1	18	2	1: .11	"	41-45	5	0	17	3	1: .18
13	46-50	5	0				13	46-50	4	1			
"	51-55	5	0				"	51-55	1	4			
"	56-60	4	1				"	56-60	4	1			
"	61-65	4	1	18	2	1: .11	"	61-65	4	1	13	7	1: .54
14	1- 5	5	0	5	0	1:0	14	1- 5	2	3			
							"	6-10	2	3	4	6	1:1.50
							15	66-70	3	2			
							"	71-75	4	1			
							"	76-80	5	0			
							"	81-85	5	0	17	3	1: .18
							"	11-15	5	0	5	0	1:0

problems, the data refer only to first choices in each trial, the column headed R containing the number of correct first choices and that headed W the number of incorrect first choices for each series of trials or for the day. It further appears from this table that five trials constituted the regular series in problem 1, and it should here be stated that the experimenter always resumed experimentation at the point in the regular series of settings at which work had been interrupted. He therefore proceeded in regular order from setting 1 to setting 10 and then returned to setting 1 and repeated the trials.

Further comment on the behavior of the animals in problem 1 is needless, for the task is but slightly more difficult than the acquisition of a simple position habit, and it has already been satisfactorily demonstrated that many of the vertebrates acquire such habits with ease.



## PROBLEM 2

For this problem, which is definable as the second mechanism from the subject's left, all of the data for discussion will be found in tables 3, 4, and 5. Again, as in the case of problem 1, the regular series consisted, throughout the training, of five trials, but as many as six such series were given on a single day. Bracketed series appearing, for example, in table 5, under the dates June 23, 24, 25, and 28 and July 1, 2, 3 and 4, were continuous, that is, ten trials were given in succession instead of only five.

For the ten settings of problem 2, the total number of open doors is fifty, and the expectation therefore is that prior to experience an animal will choose correctly once in five times, thus giving a ratio of right to wrong choices of 1 to 4. That this expected ratio does not appear on the first day of experimentation is due to the effect of the previous training in problem 1. The tendency to enter the first box at the left was persistent in both subjects and often that box was re-entered a number of times in spite of punishment. In tables 3 and 4 the data for these statements are presented, and in table 5 it may be noted that on the first day of work on problem 2 neither subject made a single correct first choice.

The ratio of correct to incorrect first choices for the female rapidly, although somewhat irregularly, decreased with experience until on July 4th it stood 1 to .19. On this date she succeeded in choosing correctly in ten successive trials, and was therefore considered to have solved the problem perfectly.

Similarly, the ratio for the male changed fairly rapidly until on July 11th it stood 1 to .11. At this time, although he had not succeeded in choosing correctly in each of the ten settings consecutively, his training was discontinued, for he had already delayed experimentation with the female for a week, and it was perfectly clear that although he made an occasional error, he was capable of perfectly solving the problem.

Whereas the female finished this problem as a result of 390 trials, the male had made only nine out of ten correct choices at the end of 520 trials, when his training was discontinued. We are inclined to think that this is a reliable indication of the difference in docility between these two individuals.

We shall now turn to tables 3 and 4 for a further brief analysis of the reactions.

For about 50 trials in problem 2, both pigs showed the effect of their experience in problem 1. Then the number of correct first choices rapidly increased for each of the ten settings. There were in the case of setting 1 few mistakes on the part of the female after 150 trials, whereas on the part of the male there were more than twice as many incorrect first choices. The same holds in general of each of the other settings, she proving herself much more steady and predictable in response than he. This was doubtless due in a measure to hunger, for it was much more difficult to keep him in the proper condition of eagerness for food than her.

The data of these tables indicate no definite and persistent reactive tendencies during the course of experimentation other than the original acquired tendency to enter the first box at the right in the group and the subsequently acquired tendency to select the second box from the left in the group. Certain of the settings proved very much more difficult than others. Contrary to expectation, difficultness is not directly variable with the number of doors open. Setting 1, for example, as contrasted with setting 6, is much the easier, yet three doors are open in each case. In general, however, it is evidently true that the larger the group of open doors the more difficult it is for the animal to choose correctly and the larger the number of mistakes in a given trial, if the first choice is not correct.

From the behavior of the two pigs in this problem, as contrasted with the first, it is safe to conclude that they are perfectly capable of selecting the proper reaction, mechanism by its relation in a group of similar mechanisms when the number in the group is as large as nine and when the constant relation of the correct mechanism is second from one end. It is further clear that this problem is a much more difficult one for the pigs than problem 1. But it is also certain that the difference in difficultness is not indicated by the difference in the number of experiences necessary for the solution of the problems, since the early days of work on problem 2 served merely to overcome the tendency acquired in connection with problem 1. It seems probable that should we subtract 100 trials from the totals under problem 2 we should have a fair basis of comparison

TABLE 3  
RESULTS FOR FEMALE IN PROBLEM 2

T.	S. 1 7.8.9	S. 2 1.2.3.4	S. 3 3.4.5.6.7	S. 4 1.2.3 4.5.6	S. 5 4.5.6.7.8	S. 6 1.2.3	S. 7 2.3.4.5	S. 8 1.2.3.4.5 6.7.8.9	S. 9 1.2.3.4	S. 10 3.4.5 6.7.8
1	7.8	1.1.1 7.4.3at	3	4	5	6	7	8	9	10
11	8	12	13	14	15	16	17	18	19	20
21	7.8	22	23	24	25	26	27	28	29	30
31	7.8	32	33	34	35	36	37	38	39	40
41	7.9.8	42	43	44	45	46	47	48	49	50
51	8	52	53	54	55	56	57	58	59	60
61	8	62	63	64	65	66	67	68	69	70
66	7.8	67	68	69	70	71	72	73	74	75
76	7.9.7.8	77	78	79	80	81	82	83	84	85
86	7.8	87	88	89	90	91	92	93	94	95
96	8	97	98	99	100	101	102	103	104	105
106	7.8	107	108	109	110	111	112	113	114	115
116	7.7.8	117	118	119	120	121	122	123	124	125
126	7.8	127	128	129	130	131	132	133	134	135
136	7.8	137	138	139	140	141	142	143	144	145
146	7.9.7.8	147	148	149	150	151	152	153	154	155
156	7.8	157	158	159	160	161	162	163	164	165
166	7.8	167	168	169	170	171	172	173	174	175
176	8	177	178	179	180	181	182	183	184	185
186	8	187	188	189	190	191	192	193	194	195
196	8	197	198	199	200	201	202	203	204	205



206	8	207	3	208	7.6	209	2.5	210	8.7	211	1.3.2	212	4	213	8	214	3	215	8.7
216	8	217	3	218	7.6	219	3.5	220	8.7	221	2	222	5.3.4	223	7.7.8	224	3	225	8.6.7
226	8	227	4.3	228	6	229	6.5	230	8.7	231	3.2	232	4	233	8	234	3	235	3.6.7
236	8	237	3	238	7.6	239	6.5	240	8.7	241	2	242	4	243	8	244	3	245	7
246	8	247	3	248	6	249	4.3.5	250	7	251	2	252	4	253	8	254	3	255	7
256	8	257	3	258	7.6	259	3.5	260	8.7	261	3.2	262	5.3.2.5.4	263	8	264	3	265	7
266	8	267	3	268	6	269	5	270	8.6.7	271	2	272	3.5.4	273	8	274	4.3	275	7
276	8	277	4.3	278	6	279	6.5	280	8.7	281	3.2	282	4	283	8	284	3	285	7
286	8	287	4.2.3	288	6	289	5	290	7	291	3.2	292	4	293	7.8	294	4.3	295	7
296	8	297	3	298	6	299	5	300	7	301	3.2	302	5.4	303	8	304	3	305	8.7
306	8	307	4.3	308	7.6	309	5	310	7	311	3.2	312	4	313	8	314	3	315	7
316	8	317	3	318	6	319	5	320	7	321	3.2	322	5.4	323	7.8	324	3	325	7
326	8	327	3	328	6	329	5	330	7	331	2	332	4	333	7.6.8	334	3	335	7
336	8	337	4.3	338	6	339	5	340	7	341	3.2	342	4	343	8	344	3	345	7
346	8	347	3	348	6	349	5	350	7	351	2	352	3.2.2.5.4	353	7.6.8	354	4.3	355	7
356	8	357	3	358	6	359	6.5	360	7	361	3.2	362	5.4	363	8	364	3	365	7
366	8	367	3	368	6	369	4.5	370	7	371	3.2	372	4	373	7.8	374	3	375	7
376	7.8	377	3	378	6	379	5	380	7	381	2	382	4	383	8	384	3	385	7
386	8	387	3	388	6	389	5	390	7	396	2	397	4	398	8	399	3	400	7
391	8	392	3	393	6	394	5	395	6.7										

\* Setting 3 was changed in this series and the succeeding series from 3.4.5.6.7 to 2.3.4.5.6.7 in order to make the ratio of right doors to wrong doors in the series of ten settings 10:40.

† The letter "a" indicates that the pig was aided in choosing the right door.

TABLE 4  
RESULTS FOR MALE IN PROBLEM 2

T.	S. 1 7.8.9	T.	S. 2 1.2.3.4	T.	S. 3 3.4.5.6.7	T.	S. 4 1.2.3 4.5.6	T.	S. 5 4.5.6.7.8	T.	S. 6 1.2.3	T.	S. 7 2.3.4.5	T.	S. 8 1.2.3.4.5 6.7.8.9	T.	S. 9 1.2.3.4	T.	S. 10 3.4.5 6.7.8
1	7.7.7 7.7.7 9.7.8	2	1.4.1.3	3	3.3.6	4	1.5	5	6.4.7	6	1.1.2	7	5.2.5.2 5.3.5.4	8	1.5.8	9	4.1.4.2 1.4.1 2.4.1.3	10	8.7
11	8	12	4.1.2 4.3 2.4.1	13	7.6	14	6.4.1 6.2.4 6.3.5	15	7	16	3.1.3 1.3.2	17	5.2.5.3 2.5.4	18	7.9.8	19	3	20	8.7
21	8	22	4.3 3	23	7.6	24	6.5	25	8.8.7	26	1.3.2	27	2.5.5.4	28	8	29	4.2.1 4.2.3	30	8.7
31	8	32	4.2.3	33	7.3.4.3.6	34	6.5	35	8.4.6.4.7	36	1.3.2	37	5.2.4	38	9.6.8	39	3	40	8.3.7
41	8	42	4.2.3	43	7.6	44	6.6.3.2 4.3.5	45	8.7	46	3.2	47	5.4	48	7.6.4.3 2.1.9.8	49	3	50	8.7
51	8	52	4.3	53	7.6	54	5	55	8.7	56	1.3.2	57	5.4	58	7.8	59	3	60	8.7
61	8	62	3	63	6	64	3.6.5	65	4.8.7	71	2	72	5.3.2.5.4	73	8	74	4.3	75	8.7
66	8	67	3	68	7.6	69	4.3.5	70	8.7	81	3.2	82	5.2.2.4	83	8	84	4.3	85	7
76	9.7.8	77	4.3	78	3.3.7.6	79	1.3.2.5	80	8.7	91	2	92	5.4	93	8	94	3	95	6.5.4 3.8.7
86	8	87	3	88	7.6	89	5	90	8.7	101	2	102	4	103	7.6.4.8	104	4.2.3	105	8.7
96	7.7.9.8	97	3	98	5.3.7.6	99	2.5	100	4.8.7	110	3.2	112	5.4	113	8	114	3	115	8.7
106	9.8	107	4.3	108	7.6*	109	4.3.2.5	110	8.7	121	3.2	122	5.4	123	7.6.5	124	3	125	8.7
116	8	117	3	118	6	119	5	120	8.7	131	2	132	3.4	133	8	134	3	135	8.7
126	8	127	4.3	128	7.6	129	5	130	8.6.5.7	141	2	142	5.4	143	8	144	3	145	3.7
136	8	137	2.4.3	138	6	139	6.5	140	8.7	151	3.2	152	5.4	153	8	154	3	155	8.7
146	8	147	3	148	6	149	5	150	7	161	3.2	162	5.2.5.5.4	163	7.6.8	164	3	165	7
156	8	157	2.1.4.3	158	6	159	5	160	7	171	3.3.2	172	5.3.2.5.4	173	8	174	3	175	8.7
166	8	167	3	168	6	169	5	170	7	181	2	182	4	183	8	184	3	185	5.7
176	8	177	3	178	5.4.3.7.6	179	2.3.5	180	8.7	191	2	192	4	193	8	194	4.3	195	8.7
186	7.8	187	3	188	7.3.6	189	4.5	190	6.8.7	201	3.2	202	5.4	203	8	204	3	205	7
196	8	197	4.3	198	7.6	199	2.3.5	200	8.7	211	3.2	212	5.4	213	8	214	3	215	8.7
206	8	207	3	208	7.6	209	5	210	8.7	221	2	222	5.4	223	8	224	3	225	8.7
216	7.8	217	3	218	5.4.7.6	219	5	220	8.7	221	2	222	5.4	223	8	224	3	225	8.7

226	8	227	4.3	228	7.6	229	5	230	8.7	231	3.2	232	5.4	233	8	234	3	235	7
236	8	237	3	238	6	239	5	240	8.7	241	3.2	242	5.4	243	7.6.4.3	244	3	245	7
246	8	247	3	248	6	249	5	250	8.7	251	3.2	252	5.4	253	8	254	3	255	5.4.3.7
256	8	257	3	258	5.4.3.2.6	259	5	260	8.6.5.4.7	261	2	262	4	263	8	264	3	265	6.5.4.3.7
266	8	267	2.3	268	6	269	5	270	7	271	3.2	272	5.4	273	8	274	4.2.3	275	7
276	7.8	277	3	278	3.2.5	279	6.5	280	7	281	2	282	3.4	283	8	284	3	285	7
					1.2.6														
286	7.8	287	3	288	5.6	289	3.4.6.5	290	7.5.7	291	2	292	2.3.5.4	293	7.6.8	294	3	295	5.6.5.8.7
296	8	297	3	298	5.4.3.7.6	299	5	300	7	301	2	302	5.4	303	8	304	2.3	305	7
306	8	307	3	308	7.6	309	5	310	5.4.8.7	311	3.2	312	5.4	313	8	314	3	315	7
316	8	317	3	318	5.6	319	4.6.2.5	320	7	321	2	322	4	323	7.6.5.4	324	3	325	4.8.7
															3.2.7.8				
326	8	327	3	328	6	329	4.3.2.1.5	330	7	331	2	332	5.4	333	8	334	3	335	6.5.7
336	8	337	3	338	6	339	5	340	4.6.5.7	341	3.2	342	5.4	343	8	344	4.3	345	7
346	7.9.8	347	3	348	5.4.5.6	349	5	350	5.5.7	351	2	352	3.4	353	8	354	3	355	5.6.8.7
356	8	357	4.3	358	7.6	359	6.5	360	7	361	3.2	362	5.4	363	8	364	3	365	7
366	8	367	4.3	368	6	369	5	370	7	371	3.2	372	3.5.4	373	8	374	3	375	7
376	8	377	4.3	378	6	379	6.5	380	7	381	3.2	382	2.4	383	8	384	3	385	7
386	8	387	4.3	388	7.6	389	5	390	7	396	3.2	397	5.4	398	8	399	2.3	400	7
391	8	392	3	393	6	394	5	395	7	406	3.2	407	4	408	7.6.5.8	409	2.4.3	410	8.4.3.6
401	8	402	4.3	403	7.6	404	5	405	7	416	3.2	417	5.4	418	7.6.8	419	2.3	420	5.8.6.7
																			7.6.8.5.7
411	7.8	412	3	413	6	414	4.5	415	7	431	3.2	432	5.4	433	8	434	4.3	435	8.7
421	8	422	3	423	7.5.3	424	5	425	7	441	3.2	442	5.4	443	7.6.8	444	3	445	7
					2.6										8				
426	8	427	4.3	428	7.6	429	5	430	8.7	431	3.2	432	5.4	433	8	434	4.3	435	8.7
436	8	437	3	438	5.7.6	439	3.2.1.5	440	7	441	3.2	442	5.4	443	7.6.8	444	3	445	7
446	8	447	3	448	6	449	5	450	8.7	451	3.2	452	5.3.4	453	8	454	3	455	7
456	8	457	3	458	6	459	5	460	7	461	3.2	462	5.4	463	7.6.8	464	3	465	7
466	8	467	3	468	5.4.7.6	469	5	470	7	476	3.2	477	5.4	478	7.6.8	479	3	480	6.5.7
471	8	472	3	473	6	474	5	475	7	476	3.2	477	5.4	478	7.6.8	479	3	480	6.5.7
481	7.8	482	3	483	6	484	4.3.2.5	485	6.5.7	486	3.2	487	5.4	488	7.5.8	489	3	490	5.7
491	8	492	3	493	6	494	3.2.5	495	6.4.7	496	2	497	3.4	498	7.8	499	3	500	7
501	8	502	3	503	6	504	5	505	6.7	506	3.2	507	5.4	508	7.8	509	3	510	7
511	8	512	3	513	6	514	5	515	7	516	2	517	4	518	7.8	519	3	520	7

\* Setting 3 was changed in this series and the succeeding ones from 3.4.5.6.7 to 2.3.4.5.6.7 in order to make the ratio of right doors to wrong doors in the series of ten settings 10:50.



TABLE 5  
DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
FIRST CHOICES

Female							Male						
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
June 16	1- 5	0	5				June 16	1- 5	0	5			
"	6-10	0	5	0	10	0:1	"	6-10	0	5	0	10	0:1
17	11-15	2	3				17	11-15	2	3			
"	16-20	0	5				"	16-20	1	4			
"	21-25	0	5	2	13	1:6.50	"	21-25	1	4	4	11	1:2.75
18	26-30	2	3				18	26-30	1	4			
"	31-35	1	4				"	31-35	2	3			
"	36-40	0	5				"	36-40	1	4			
"	41-45	1	4	4	16	1:4.00	"	41-45	1	4	5	15	1:3.00
19	46-50	1	4				19	46-50	1	4			
"	51-55	4	1				"	51-55	2	3			
"	56-60	2	3				"	56-60	1	4			
"	61-65	1	4	8	12	1:1.50	"	61-65	3	2	6	9	1:1.50
20	66-70	1	4				20	66-70	2	3			
"	71-75	2	3				"	71-75	2	3			
"	76-80	0	5				"	76-80	0	5			
"	81-85	2	3	5	15	1:3.00	"	81-85	2	3	6	14	1:2.33
21	86-90	0	5				21	86-90	3	2			
"	91-95	0	5				"	91-95	3	2			
"	96-100	2	3				"	96-100	1	4			
"	101-	1	4	3	17	1:5.67	"	101-	2	3	9	11	1:1.22
22	106-	0	5				22	106-	0	5			
"	111-	2	3				"	111-	2	3			
"	116-	0	5				"	116-	4	1			
"	121-	1	4	3	17	1:5.67	"	121-	1	4	7	13	1:1.86
23	126-	1	4				23	126-	2	3			
"	131-	1	4				"	131-	3	2			
"	136-	2	3				"	136-	2	3			
"	141-	1	4				"	141-	3	2			
"	146-	2	3	7	18	1:2.57	"	146-	5	0	15	10	1: .67
24	151-	1	4				24	151-	2	3			
"	156-	1	4				"	156-	4	1			
"	161-	3	2				"	161-	2	3			
"	166-	3	2				"	166-	5	0			
"	171-	4	1	12	13	1:1.08	"	171-	2	3	15	10	1: .67
25	176-	2	3				25	176-	2	3			
"	181-	3	2				"	181-	4	1			
"	186-	3	2				"	186-	1	4			
"	191-	3	2	11	9	1: .82	"	191-	3	2	10	10	1:1
26	196-	1	4				26	196-	1	4			
"	201-	3	2				"	201-	3	2			
"	206-	2	3	6	9	1:1.50	"	206-	3	2	7	8	1:1.14
27	211-	3	2				27	211-	2	3			
"	216-	2	3				"	216-	2	3			
"	221-	2	3	7	8	1:1.14	"	221-	3	2	7	8	1:1.14
28	226-	2	3				28	226-	2	3			
"	231-	3	2				"	231-	3	2			
"	236-	2	3				"	236-	4	1			
"	241-	5	0				"	241-	2	3			
"	246-	4	1				"	246-	4	1			
"	251-	5	0	21	9	1: .43	"	251-	2	3	17	13	1: .76
29	256-	2	3				29	256-	3	2			

TABLE 5—*Continued*  
 DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
 FIRST CHOICES  
 PROBLEM 2

Female							Male						
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
June 29	261	3	2				June 29	261	4	1			
"	266	4	1				"	266	4	1			
"	271	3	2				"	271	2	3			
"	276	2	3				"	276	2	3			
"	281	4	1	18	12	1: .67	"	281	4	1	19	11	1: .58
30	286	4	1				30	286	1	4			
"	291	2	3				"	291	2	3			
"	296	5	0				"	296	4	1			
"	301	2	3	13	7	1: .54	"	301	3	2	10	10	1:1
July 1	306	3	2				July 1	306	3	2			
"	311	4	1				"	311	3	2			
"	316	5	0				"	316	3	2			
"	321	2	3	14	6	1: .43	"	321	2	3	11	9	1: .82
2	326	5	0				2	326	4	1			
"	331	4	1				"	331	3	2			
"	336	4	1				"	336	4	1			
"	341	4	1	17	3	1: .18	"	341	2	2	13	7	1: .54
3	346	5	0				3	346	2	3			
"	351	2	3				"	351	3	2			
"	356	4	1				"	356	2	3			
"	361	3	2	14	6	1: .43	"	361	3	2	10	10	1:1
4	366	4	1				4	366	4	1			
"	371	3	2				"	371	3	2			
"	376	4	1				"	376	3	2			
"	381	5	0				"	381	3	2			
"	386	5	0	21	4	1: .19	"	386	3	2	16	9	1: .56
11	391	4	1				5	391	5	0			
"	396	5	0	9	1	1: .11	"	396	2	3			
							"	401	3	2			
							"	406	1	4			
							"	411	3	2	14	11	1: .79
							6	416	0	5			
							"	421	4	1	4	6	1:1.50
							7	426	2	3			
							"	431	1	4			
							"	436	3	2			
							"	441	2	3	8	12	1:1.50
							8	446	4	1			
							"	451	3	2			
							"	456	5	0			
							"	461	2	3			
							"	466	4	1	18	7	1: .39
							9	471	5	0			
							"	476	1	4			
							"	481	2	3			
							"	486	1	4	9	11	1:1.22
							10	491	3	2			
							"	496	3	2			
							"	501	4	1			
							"	506	2	3	12	8	1: .67
							11	511	5	0			
							"	516	4	1	9	1	1: .11

with problem 1. It would then appear to be from four to eight times as difficult as the latter.

One important aspect of the experiment should be here considered. According to our procedure, one of the pigs led and the other followed in a series of trials. It was therefore possible that the follower might be aided in its choice either by watching its companion or by the odor of the box in which the animal fed. There can be no doubt of the tendency of the pigs both to watch one another and to be influenced by the odor of the boxes, but that the solution of the problems did not depend upon either of these factors, although the number of trials necessary to solution may have been modified thereby, is proved by the fact that both subjects made ninety per cent of correct choices when leading.

### PROBLEM 3

All of the data in connection with this problem are to be found in tables 6, 7, and 8. The problem is definable as alternately the first mechanism at the right and the first at the left. At the beginning of work on this problem, the animals were given their trials alternately as in the preceding problems, but a strong tendency to follow manifested itself, and on the second day the trials were given by pairs. That is, each individual was allowed to choose in succession the first door at its right and the first door at its left, and was then required to wait while its companion responded to the same pair of settings. Thus, following was rendered impossible.

The tendency to choose the second door from the left naturally manifested itself in the early work on this problem, but it was soon destroyed by training, and the course of experimentation proceeded smoothly to the perfect solution of the problem.

It is to be noted that from the first, ten trials constituted a series. Because of the familiarity with the general experimental situation which the animals had acquired and the experience of the experimenters in the control of hunger and punishment, it was easier to obtain reactions to ten successive trials at this time in the investigation than to five early in the work, with problems 1 or 2.

The female succeeded in solving problem 3 as the result of 420 trials; the male, as the result of 470.

For this problem as for problem 2, the expectation prior to experience is one correct first choice to four incorrect first choices. The male in his first series exhibited exactly this ratio, whereas the female gave a ratio of 1 to 1. Her success, however, was undoubtedly due to following, for in immediately subsequent trials when following was rendered impossible by the giving of the trials by pairs, she did very poorly. The daily ratios for each individual, as presented in table 8, are of interest, but they are by no means as important as are the detailed data of tables 6 and 7.

As might have been expected, after the previously acquired tendency to select the first mechanism at the left had been overcome, the pigs shortly exhibited the tendency to select the end boxes, and they then had to overcome the difficulty of selecting the right end. It is quite possible that this task was rendered easier by the rhythm which resulted from the giving of trials by pairs, but it was perfectly evident from control experiments that the animals could choose correctly even if given their trials in rapid succession, without the irregularity due to alternate experimenting with the two individuals.

Since it seemed possible that the animals might have learned the proper settings and be responding to definite situations rather than to the relation of the right box to the other members of the group, a control experiment was made by the presentation of a new series of settings. At the bottoms of tables 6 and 7 appear the results of these control observations.

The female had solved problem 3 on the completion of trial 420 (see tables 6 and 8), and the male on the completion of trial 470 (see tables 7 and 8). The next series of ten trials for each was preliminary to the control experiments and served also as a demonstration series to certain other observers. Following this demonstration in which both pigs reacted fairly well, the series of settings indicated in tables 6 and 7 was presented. Both individuals were somewhat disturbed by the change, her record being seven correct choices out of ten, and his nine out of ten. Later in the day another series of ten trials, according to the original settings, was given with the result that the female made three incorrect first choices in ten and the male two. Still later, the control settings were again presented. This time she chose correctly eight times in ten and he only five times.



TABLE 6  
RESULTS FOR FEMALE IN PROBLEM 3

T.	S. 1 5.6.7	T.	S. 2 5.6.7	T.	S. 3 1.2.3 4.5.6	T.	S. 4 1.2.3 4.5.6	T.	S. 5 4.5.6.7.8	T.	S. 6 4.5.6.7.8	T.	S. 7 2.3.4.5	T.	S. 8 2.3.4.5	T.	S. 9 3.4.5.6 7.8.9	T.	S. 10 3.4.5.6 7.8.9
1	7.5	2	6.5.7	3	{3.5.4.6 5.3.2.5 4.3.6.5 4.1 2.3.1}	4	6	5	4	6	8	7	2	8	3.4.3.5	9	{8.7.6.7 5.8.4.7.9 5.8.6 7.3}	10	9
11	7.6.5	12	6.7	13	{5.6.4 2.1 2.3.1}	14	5.4.3.6	15	7.5.6.4	16	7.8	17	4.2	18	3.5	19	8.7.6.3	20	4.7.8.9
21	7.6.5	22	5.7	23	2.1	24	3.6	25	8.7.6.5.4	26	8	27	2	28	5	29	9.7.3	30	7.8.7.6.9
31	7.6.7.5	32	5.7	33	4.2.1	34	3.6	35	8.4	36	4.7.5.4.8	37	3.2	38	5	39	8.7.3	40	6.5.8.7.9
41	5	42	5.6.7	43	2.1	44	3.4.6	45	4	46	6.8	47	3.2	48	5	49	9.5.3	50	{8.6.3 8.4.9}
51	7.6.5	52	5.7	53	2.3.1	54	6	55	8.4	56	6.4.5.7.8	57	2	58	5	59	3	60	7.8.9
61	5	62	7	63	3.2.6.5.1	64	4.6	65	5.7.8.4	66	6.4.6.8	67	2	68	3.5	69	6.9.3	70	4.8.6.9
71	5	72	7	73	5.3.1	74	6	75	8.4	76	7.8	77	2	78	3.5	79	9.3	80	8.9
81	5	82	5.7	83	6.1	84	3.5.6	85	8.5.8.5.4	86	7.8	87	2	88	3.5	89	9.3	90	7.9
91	6.7.5	92	6.7	93	{2.6.4 5.6.1}	94	3.6	95	6.8.4	96	7.4.8	97	2	98	5	99	7.9.8.9.3	100	7.8.9
101	5	102	7	103	2.5.6.1	104	4.6	105	6.8.4	106	6.8	107	2	108	5	109	{8.9.6.9 7.9.3}	110	3.7.8.9
111	7.5	112	6.7	113	1	114	3.6	115	8.7.4	116	8	117	5.3.2	118	5	119	7.8.9.3	120	7.9
121	7.5	122	7	123	2.6.1	124	4.1.3.6	125	8.4	126	6.8	127	2	128	5	129	8.9.3	130	8.9
131	6.7.5	132	7	133	1	134	6	135	7.8.4	136	6.8	137	2	138	5	139	9.8.9.3	140	7.9
141	5	142	7	143	1	144	3.6	145	8.4	146	7.8	147	2	148	5	149	3	150	8.9
151	6.7.5	152	7	153	1	154	3.6	155	7.8.4	156	6.8	157	2	158	5	159	9.3	160	9
161	7.5	162	6.7	163	1	164	3.4.6	165	4	166	8	167	2	168	3.5	169	8.3	170	7.9
171	5	172	7	173	1	174	3.6	175	8.4	176	7.8	177	2	178	5	179	9.8.3	180	9
181	6.5	182	7	183	2.4.6.1	184	3.1.6	185	4	186	8	187	2	188	3.2.5	189	9.3	190	6.9
191	5	192	7	193	2.4.6.1	194	3.6	195	8.4	196	7.8	197	3.5.2	198	5	199	9.3	200	6.9
201	5	202	7	203	2.6.1	204	6	205	8.4	206	6.8	207	2	208	5	209	9.3	210	9

211	6.7.5	1212	7	213	6.1	214	6	215	7.8.5 7.8.4	216	8	217	3.5.2	218	5	219	9.3	220	9
221	5	222	7	223	2.6.1	224	6	225	4	226	8	227	2	228	5	229	9.3	230	9
231	5	232	7	233	2.1	234	6	235	4	236	8	237	2	238	3.5	239	3	240	9
241	5	242	5.7	243	1	244	6	245	4	246	8	247	2	248	3.5	249	3	250	9
251	5	252	7	253	1	254	2.6	255	4	256	8	257	2	258	3.5	259	3	260	9
261	5	262	7	263	1	264	6	265	4	266	8	267	2	268	5	269	9.3	270	9
271	5	272	7	273	1	274	3.6	275	4	276	8	277	2	278	4.5	279	3	280	9
281	5	282	5.7	283	1	284	3.6	285	8.4	286	8	287	2	288	5	289	3	290	9
291	5	292	7	293	1	294	3.6	295	8.4	296	8	297	2	298	5	299	9.3	300	9
301	5	302	7	303	1	304	6	305	8.4	306	7.8	307	2	308	3.5	309	3	310	9
311	5	312	7	313	1	314	6	315	8.4	316	8	317	2	318	5	319	3	320	9
321	7.5	322	7	323	1	324	5.6	325	4	326	8	327	2	328	4.5	329	9.3	330	9
331	5	332	7	333	1	334	6	335	4	336	8	337	2	338	3.5	339	3	340	9
341	6.5	342	7	343	2.1	344	6	345	4	346	8	347	2	348	5	349	9.3	350	8.9
351	5	352	7	353	1	354	3.6	355	4	356	8	357	2	358	5	359	3	360	9
361	5	362	7	363	1	364	6	365	4	366	8	367	2	368	5	369	9.3	370	9
371	6.5	372	7	373	1	374	6	375	4	376	8	377	2	378	5	379	3	380	9
381	5	382	7	383	1	384	4.6	385	4	386	8	387	2	388	4.5	389	9.3	390	9
391	5	392	7	393	1	394	6	395	8.4	396	8	397	2	398	5	399	3	400	9
401	6.5	402	7	403	2.1	404	6	405	4	406	8	407	2	408	5	409	3	410	9
411	5	412	7	413	1	414	6	415	4	416	8	417	2	418	5	419	3	420	9
421	5	422	6.7	423	1	424	6	425	5.4	426	7.8	427	2	428	5	429	3	430	9
					4.5.6 7.8.9		4.5.6 7.8.9		1.2.3.4.5		1.2.3.4.5		2.3.4 5.6.7		2.3.4 5.6.7		3.4.5 6.7.8		3.4.5 6.7.8
1	4.6.3	2	6	3	4	4	9	5	2.1	6	5	7	7.2	8	7	9	3	10	8
431	5	432	7	433	1	434	6	435	6.8.4	436	7.8	437	2	438	5	439	9.3	440	9
					4.5.6 7.8.9		4.5.6 7.8.9		1.2.3.4.5		1.2.3.4.5		2.3.4 5.6.7		2.3.4 5.6.7		3.4.5 6.7.8		3.4.5 6.7.8
11	3	12	6	13	5.9.4	14	9	15	1	16	5	17	2	18	7	19	5.3	20	8

TABLE 7  
RESULTS FOR MALE IN PROBLEM 3

T.	S. 1 5.6.7	T.	S. 2 5.6.7	T.	S. 3 1.2.3 4.5.6	T.	S. 4 1.2.3 4.5.6	T.	S. 5 4.5.6.7.8	T.	S. 6 4.5.6.7.8	T.	S. 7 2.3.4.5	T.	S. 8 2.3.4.5	T.	S. 9 3.4.5.6 7.8.9	T.	S. 10 3.4.5.6 7.8.9
1	6.5	2	7		5.4.3.2 6.5.3 4.2.5 3.5.1 2.1	3	1.3.5.5.6	4	7.6.4	5	7.6.8	6	5.4.3.2	7	5	9	8.7.6.8 7.7.3	10	5.7.8.9
11	6.5	12	6.7		5.4.3.6 2.1	13	5.4.3.6	14	7.8.5.4	15	8	16	2	17	5	19	3	20	8.7.9
21	6.5	22	7		5.4.3.2 6.5.1	23	3.2.6	24	8.7.4	25	6.8	26	3.5.2	27	3.5	29	8.7.9 8.6.3 7.6.9	30	8.7.5 4.8.9
31	7.6.5	32	7		5.4.3.2.1	33	5.4.3.5.6	34	8.6.8.7.4	35	8	36	3.2	37	2.5	39	8.7.3 9.7.6.8 9.8.5.4	40	8.9
41	7.6.5	42	7		5.3.2.4.1	43	5.2.1.4.6	44	7.8.6.7.4	45	8	46	5.2	47	2.4.3.2.5	49	8.7.4.6 18.3	50	9
51	6.7.5	52	5.7		3.1	53	2.5.6	54	8.6.4	55	8	56	3.5.2	57	4.5	59	9.8.3	60	6.3.8.7.9
61	7.5	62	6.5.7		3.1	63	2.6	64	7.8.7.4	65	8	66	4.2	67	3.5	69	9.3	70	7.9
71	7.5	72	6.7		5.1	73	2.1.4.2.6	74	4	75	6.8	76	5.2	77	3.5	79	9.5.3	80	9
81	7.5	82	6.7		1	83	3.4.6	84	8.7.8.4	85	7.8	86	2	87	3.5	89	9.3	90	9
91	6.5	92	7		3.1	93	6	94	8.4	95	8	96	3.5.2	97	5	99	9.4.8.9 14.8.9.3	100	6.9
101	5	102	7		4.1	103	6	104	8.5.8 6.8.4	105	5.8	106	3.2	107	5	109	9.3	110	8.9
111	7.5	112	6.7		3.1	113	4.6	114	8.4	115	8	116	3.5.2	117	5	119	9.3	120	9
121	6.7.5	122	6.7		3.1	123	5.1.6	124	6.4	125	8	126	3.2	127	5	129	9.3	130	9
131	7.5	132	7		3.1	133	6	134	8.4	135	7.8	136	2	137	5	139	8.9.3	140	9
141	6.5	142	7		1	143	3.4.3.2.6	144	4	145	8	146	2	147	3.5	149	4.9.7.4 9.5.8.3	150	9
151	7.5	152	7		2.6.4.2.1	153	2.5.3.6	154	8.4	155	8	156	3.2	157	3.5	159	9.3	160	9
161	6.5	162	7		2.6.4.6 2.6.1	163	3.2.6	164	8.5.4	165	8	166	3.5.2	167	5	169	9.3	170	9
171	7.5	172	7		1	173	3.5.3.2.6	174	4	175	7.8	176	2	177	3.5	179	3	180	9
181	5	182	7		2.6.1	183	3.6	184	8.4	185	8	186	2	187	3.5	189	3	190	9
191	5	192	7		1	193	2.6	194	7.5.4	195	8	196	2	197	3.5	199	9.3	200	9
201	7.5	202	7		3.1	203	6	204	4	205	8	206	2	207	2.5	209	9.3	210	9

211	7.5	212	7	213	2.6.1	214	3.6	215	8.6.4	216	8	217	2	218	5	219	9.3	220	9
221	5	222	7	223	2.6.1	224	2.1.6	225	4	226	8	227	3.2	228	2.5	229	9.3	230	9
231	6.5	232	7	233	1	234	2.2.6	235	7.4	236	8	237	3.2	238	2.5	239	9.3	240	9
241	7.5	242	7	243	2.6.4.1	244	5.2.6	245	4	246	8	247	3.5.2	248	3.5	249	3	250	9
251	6.5	252	7	253	1	254	3.6	255	8.4	256	8	257	2	258	3.5	259	3	260	9
261	7.5	262	7	263	3.5.1	264	6	265	4	266	8	267	2	268	4.5	269	9.3	270	9
271	5	272	7	273	1	274	6	275	4	276	8	277	2	278	3.5	279	3	280	9
281	5	282	7	283	1	284	3.6	285	4	286	8	287	2	288	5	289	3	290	9
291	7.5	292	7	293	2.3.1	294	6	295	4	296	8	297	2	298	4.5	299	3	300	9
301	7.5	302	7	303	1	304	6	305	4	306	8	307	2	308	5	309	9.3	310	9
311	6.5	312	7	313	2.5.6.1	314	6	315	4	316	8	317	2	318	5	319	9.3	320	9
321	5	322	7	323	1	324	6	325	8.4	326	8	327	2	328	5	329	9.3	330	9
331	5	332	7	333	1	334	5.4.6	335	4	336	8	337	2	338	5	339	3	340	9
341	7.5	342	7	343	2.6.1	344	6	345	4	346	8	347	2	348	5	349	3	350	9
351	7.5	352	7	353	1	354	4.6	355	4	356	8	357	2	358	5	359	3	360	9
361	6.5	362	5.7	363	1	364	2.6	365	4	366	8	367	2	368	3.5	369	3	370	9
371	5	372	7	373	1	374	6	375	4	376	8	377	2	378	5	379	9.3	380	9
381	7.5	382	7	383	2.1	384	6	385	4	386	8	387	2	388	5	389	3	390	9
391	5	392	7	393	2.4.6.1	394	6	395	4	396	8	397	2	398	5	399	3	400	9
401	5	402	7	403	1	404	4.3.6	405	4	406	8	407	2	408	3.5	409	3	410	9
411	5	412	7	413	1	414	4.2.6	415	4	416	8	417	2	418	5	419	3	420	8.3.9
421	5	422	7	423	2.6.1	424	6	425	8.4	426	8	427	2	428	5	429	3	430	9
431	5	432	7	433	6.1	434	6	435	4	436	8	437	2	438	4.5	439	3	440	9
441	5	442	6.7	443	1	444	6	445	5.8.4	446	8	447	2	448	5	449	3	450	9
451	5	452	7	453	1	454	6	455	7.4	456	8	457	3.5.2	458	4.5	459	9.3	460	9
461	5	462	7	463	1	464	6	465	4	466	8	467	2	468	5	469	3	470	9
471	7.5	472	7	473	1	474	6	475	8.4	476	8	477	2	478	5	479	3	480	9
					4.5.6 7.8.9		4.5.6 7.8.9		1.2.3.4.5		1.2.3.4.5		2.3.4 5.6.7		2.3.4 5.6.7		3.4.5 6.7.8		3.4.5 6.7.8
1	3	2	6	3	4	4	9	5	1	6	5	7	2	8	7	9	4.3	10	8
481	6.5	482	7	483	2.6.1	484	6	485	4	486	8	487	2	488	5	489	3	490	9
					4.5.6 7.8.9		4.5.6 7.8.9		1.2.3.4.5		1.2.3.4.5		2.3.4 5.6.7		2.3.4 5.6.7		3.4.5 6.7.8		3.4.5 6.7.8
11	5.3	12	6	13	5.4	14	9	15	2.5.1	16	5	17	5.2	18	7	19	7.3	20	8



TABLE 8  
DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
FIRST CHOICES

Female							Male						
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
July 11	1-	5	5	5	5	1:1	July 11	1-	2	8	2	8	1:4.00
12	11-	0	10				12	11-	4	6			
"	21-	3	7	3	17	1:5.66	"	21-	1	9	5	15	1:3.00
13	31-	1	9				13	31-	2	8			
"	41-	3	7	4	16	1:4.00	"	41-	3	7	5	15	1:3.00
14	51-	4	6				14	51-	1	9			
"	61-	3	7	7	13	1:1.86	"	61-	1	9	2	18	1:9.00
15	71-	4	6				15	71-	2	8			
"	81-	2	8	6	14	1:2.33	"	81-	3	7	5	15	1:3.00
16	91-	2	8				16	91-	4	6			
"	101-	4	6	6	14	1:2.33	"	101-	4	6	8	12	1:1.50
17	111-	3	7				17	111-	3	7			
"	121-	3	7	6	14	1:2.33	"	121-	3	7	6	14	1:2.33
18	131-	5	5				18	131-	5	5			
"	141-	6	4				"	141-	6	4			
"	151-	5	5	16	14	1: .88	"	151-	3	7	14	16	1:1.14
19	161-	4	6				19	161-	4	6			
"	171-	6	4	10	10	1:1	"	171-	6	4	10	10	1:1
20	181-	4	6				20	181-	6	4			
"	191-	3	7	7	13	1:1.86	"	191-	6	4	12	8	1: .67
21	201-	6	4				21	201-	6	4			
"	211-	5	5	11	9	1: .82	"	211-	5	5	11	9	1: .82
22	221-	8	2				22	221-	5	5			
"	231-	7	3	15	5	1: .33	"	231-	5	5	10	10	1:1
23	241-	9	1				23	241-	5	5			
"	251-	8	2	17	3	1: .18	"	251-	6	4	11	9	1: .82
24	261-	9	1				24	261-	6	4			
"	271-	8	2				"	271-	9	1			
"	281-	7	3	24	6	1: .25	"	281-	9	1	24	6	1: .25
25	291-	7	3				25	291-	7	3			
"	301-	7	3				"	301-	8	2			
"	311-	9	1	23	7	1: .30	"	311-	7	3	22	8	1: .36
26	321-	6	4				26	321-	8	2			
"	331-	9	1	15	5	1: .33	"	331-	9	1	17	3	1: .18
27	341-	6	4				27	341-	8	2			
"	351-	9	1	15	5	1: .33	"	351-	7	3	15	5	1: .33
28	361-	9	1				28	361-	6	4			
"	371-	9	1	18	2	1: .11	"	371-	9	1	15	5	1: .33
29	381-	7	3				29	381-	8	2			
"	391-	9	1	16	4	1: .25	"	391-	9	1	17	3	1: .18
30	401-	8	2				30	401-	8	2			
"	411-	10	0	18	2	1: .11	"	411-	8	2	16	4	1: .25
							31	421-	8	2			
							"	431-	8	2	16	4	1: .25
							Aug. 1	441-	8	2			
							"	451-	6	4			
							"	461-	10	0	24	6	1: .25
2	421	7	3	7	3	1: .43	2	471	8	2	8	2	1: .25
3	1-10	7	3	7	3	1: .43	3	1-10	9	1	9	1	1: .11
3	431	7	3	7	3	1: .43	3	481	8	2	8	2	1: .25
3	11-20	8	2	8	2	1: .25	3	11-20	5	5	5	5	1:1

Although these figures are far from conclusive, we are convinced from the behavior of the animals that neither was choosing by familiarity with the particular settings. She, as has been pointed out, did as well with the control series as with the regular series, and he did even better in the first control series than in the regular series, while showing extreme confusion in the second control series. This was doubtless due to insufficient hunger and the distracting influence of a mistake in the first trial of the series. His carelessness throughout the last control series was conspicuous.

Comparison of the results for problems 2 and 3 indicate that for the female problem 3 was somewhat the more difficult, whereas for the male, problem 2 required a larger number of trials. We are by no means convinced by this comparison that the problems have not been used in the order of increasing difficulty, for we consider the female subject a much more reliable individual than the male, and we suspect that his greater facility in the solution of the third problem was due in part, at least, to the experience of the experimenters in dealing with his temperamental and other peculiarities.

#### PROBLEM 4

The data to be considered in this connection appear in tables 9, 10 and 11. The correct mechanism is definable simply as the middle one, and the expectation prior to experience is one correct to four incorrect first choices, since the total number of doors open in the series of ten settings is fifty. As is shown in table 11, precisely this ratio resulted from the first day's experimentation in the case of each individual.

Ten trials per series were given regularly throughout the work on this problem.

Unlike the preceding problems, this one proved insoluble. Consequently, the detailed results as they appear in tables 9 and 10 are especially important, since from them may be read the reactive tendencies and their relations to one another. It is, of course, easy to understand why the ratio of correct to incorrect first choices should change steadily in the direction of the solution of the problem, for each subject gradually learned to react appropriately to certain of the settings while failing to acquire the ability to react to the relation middleliness.

TABLE 9  
RESULTS FOR FEMALE IN PROBLEM 4

T.	S. 1 2.3.4	T.	S. 2 5.6.7.8.9	T.	S. 3 1.2.3.4 5.6.7	T.	S. 4 7.8.9	T.	S. 5 4.5.6.7.8	T.	S. 6 1.2.3.4.5 6.7.8.9	T.	S. 7 1.2.3	T.	S. 8 2.3.4.5.6	T.	S. 9 3.4.5.6 7.8.9	T.	S. 10 6.7.8
1	2.3	2	$\left\{ \begin{smallmatrix} 5.9.5.9 \\ 6.5.9.9 \\ 5.9.8.9 \\ 5.9.8.6 \end{smallmatrix} \right\}$ 7	3	1.7.4	4	7.9.7.8	5	4.8.4.8.6	6	1.9.5	7	1.3.2	8	$\left\{ \begin{smallmatrix} 2.5.6 \\ 2.6.3 \\ 6.5.4 \end{smallmatrix} \right\}$	9	$\left\{ \begin{smallmatrix} 3.9.5 \\ 9.3.8 \\ 9.3.6 \end{smallmatrix} \right\}$	10	6.8.7
11	3.4.3	12	$\left\{ \begin{smallmatrix} 5.8.9 \\ 6.5.9 \\ 6.8.7 \end{smallmatrix} \right\}$	13	$\left\{ \begin{smallmatrix} 1.7.3.6 \\ 1.5.3.7 \\ 2.1.6.5 \\ 2.7.5.6 \end{smallmatrix} \right\}$ 4	14	9.8	15	6	16	5	17	2	18	$\left\{ \begin{smallmatrix} 6.3.5.6 \\ 2.3.6.5 \\ 3.6.2.4 \end{smallmatrix} \right\}$	19	3.8.9.6	20	7
21	2.4.4.3	22	5.8.7	23	1.6.4	24	7.8	25	6	26	1.8.5	27	1.2	28	5.4	29	$\left\{ \begin{smallmatrix} 5.8.3 \\ 9.7.6 \end{smallmatrix} \right\}$	30	7
31	2.4.3	32	7	33	3.4	34	9.7.8	35	5.6	36	5	37	3.2	38	3.6.4	39	6	40	8.7
41	2.3	42	5.7	43	6.3.4	44	8	45	6	46	$\left\{ \begin{smallmatrix} 2.7.9.1 \\ 4.2.9.5 \end{smallmatrix} \right\}$	47	3.2	48	5.4	49	6	50	6.8.7
51	2.4.3	52	7	53	$\left\{ \begin{smallmatrix} 5.1.6.7 \\ 5.6.2.4 \end{smallmatrix} \right\}$	54	7.8	55	6	56	1.9.7.3.5	57	2	58	$\left\{ \begin{smallmatrix} 6.3.5 \\ 7.2.4 \end{smallmatrix} \right\}$	59	3.6	60	7
61	2.4.3	62	8.6.5.7	63	$\left\{ \begin{smallmatrix} 5.3.6.1 \\ 2.7.5.2 \end{smallmatrix} \right\}$	64	8	65	5.6	66	$\left\{ \begin{smallmatrix} 6.7.9 \\ 3.2.5 \end{smallmatrix} \right\}$	67	2	68	6.3.4	69	3.6	70	6.8.6.8.7
71	4.2.3	72	8.5.9.6.7	73	$\left\{ \begin{smallmatrix} 5.6.2.5 \\ 1.7.4 \end{smallmatrix} \right\}$	74	9.8	75	5.6	76	5	77	2	78	4	79	$\left\{ \begin{smallmatrix} 7.8.3.7 \\ 8.3.5.6 \end{smallmatrix} \right\}$	80	7
81	3	82	7	83	2.6.4	84	8	85	5.4.6	86	2.6.4.5	87	2	88	6.3.4	89	$\left\{ \begin{smallmatrix} 7.8.5.6 \\ 7.6 \end{smallmatrix} \right\}$	90	6.7
91	4.2.3	92	6.8.6.7	93	2.6.5.4	94	8	95	5.7.5.6	96	$\left\{ \begin{smallmatrix} 6.7.2.9 \\ 2.4.6.5 \end{smallmatrix} \right\}$	97	2	98	6.4	99	7.6	100	8.6.8.7
101	4.2.3	102	5.6.7	103	5.4	104	7.8	105	6	106	2.4.6.7.5	107	2	108	6.5.4	109	8.7.6	110	.87
111	2.3	112	8.6.7	113	2.5.4	114	8	115	5.6	116	2.4.5	117	2	118	6.6.5.4	119	6	120	6.7
121	3	122	8.6.7	123	2.5.6.4	124	7.8	125	5.6	126	1.4.3.5	127	2	128	4	129	3.6	130	7
131	3	132	7	133	4	134	8	135	6	136	5	137	2	138	6.5.6.4	139	6	140	8.7
141	4.3	142	7	143	$\left\{ \begin{smallmatrix} 2.5.6.5 \\ 6.1.4 \end{smallmatrix} \right\}$	144	8	145	7.6	146	6.5	147	2	148	6.4	149	8.9.6	150	8.7
151	3	152	7	153	$\left\{ \begin{smallmatrix} 2.5.6.7 \\ 5.2.4 \end{smallmatrix} \right\}$	154	8	155	7.6	156	7.8.4	157	2	158	5.3.6.4	159	$\left\{ \begin{smallmatrix} 8.7.3.7 \\ 8.4.6 \end{smallmatrix} \right\}$	160	6.8.7
161	2.4.3	162	7	163	4	164	8	165	6	166	2.5	167	2	168	3.4	169	8.7.4.6	170	7
171	3	172	5.7	173	2.4	174	8	175	5.6	176	2.3.5	177	2	178	3.4	179	6	180	7
181	3	182	8.7	183	2.4	184	7.8	185	5.7.6	186	2.4.7.8.5	187	2	188	4	189	8.7.6	190	8.7
191	3	192	6.7	193	2.4	194	7.8	195	5.6	196	2.4.8.4.5	197	2	198	6.3.4	199	6	200	7
201	3	202	7	203	5.4	204	7.8	205	5.6	206	2.4.5	207	2	208	4	209	6	210	6.8.7
211	3	212	6.8.5.7	213	5.4	214	7.8	215	6	216	4.6.2.5	217	2	218	6.4	219	8.7.6	220	6.7
221	3	222	6.8.5.7	223	5.6.4	224	8	225	5.6	226	5	227	2	228	6.4	229	8.7.5.6	230	7

231	3	232	7	233	4	234	8	235	6	236	2.15	237	2	238	6.5,3.4	239	6	240	7
241	3	242	6.8.7	243	4	244	8	245	5.6	246	2.4.6	247	3.2	248	6.5.4	249	8.9.5.7.6	250	8.7
251	4.3	252	7	253	4	254	8	255	5.6	256	18.9.5	257	3.2	258	3.4	259	4.5.6	260	7
261	3	262	7	263	4	264	8	265	7.6	266	2.4.5	267	2	268	5.1	269	6	270	7
271	4.3	272	8.7	273	6.5.7.4	274	8	275	6	276	16.2.6	277	3.2	278	5.4	279	6	280	7
281	4.3	282	7	283	6.4	284	8	285	6	286	8.6.1.7	287	2	288	5.4	289	6	290	7
291	4.3	292	8.6.7	293	5.6.4	294	8	295	6	296	2.6.1.5	297	3.2	298	6.5.4	299	7.6	300	7
301	3	302	6.7	303	4	304	7.8	305	6	306	1.6.5	307	3.2	308	6.5.4	309	7.8.7.6	310	8.7
311	3	312	6.5.7	313	5.6.4	314	8	315	5.6	316	1.7.6.2	317	3.2	318	4	319	4.7.6	320	8.6.7
321	4.3	322	6.8.7	323	7.6.2.4	324	8	325	7.5.6	326	1.3.5	327	2	328	6.4	329	8.6	330	7
331	3	332	6.7	333	4	334	8	335	4.5.6	336	2.4.5	337	2	338	6.4	339	6	340	7
341	4.3	342	7	343	2.4	344	8	345	4.6	346	2.4.6	347	2	348	6.4	349	8.1.6	350	7
351	3	352	6.6.8.7	353	5.6.4	354	8	355	5.6	356	6.7.5	357	2	358	4	359	8.7.6	360	8.7
361	4.3	362	6.8.5.7	363	4	364	7.8	365	5.6	366	5	367	2	368	6.5.4	369	8.7.5.6	370	7
371	4.3	372	7	373	5.6.4	374	8	375	7.6	376	7.8.6.4.5	377	2	378	6.4	379	7.6	380	7
381	4.3	382	8.7	383	6.5.4	384	8	385	6	386	5	387	2	388	6.5.4	389	7.6	390	7
391	3	392	8.7	393	5.6.4	394	8	395	5.6	396	6.5	397	2	398	5.4	399	6	400	7
401	3	402	7	403	5.6.4	404	8	405	4.5.6	406	2.4.5	407	2	408	4	409	6	410	7
411	3	412	7	413	2.4	414	8	415	5.6	416	2.4.5	417	2	418	3.4	419	6	420	7
421	3	422	6.7	423	4	424	8	425	6	426	2.5	427	2	428	2.4	429	6	430	7
431	3	432	6.7	433	2.6.5.4	434	8	435	4.5.6	436	2.4.5	437	2	438	3.4	439	6	440	8.7
441	3	442	8.7	443	2.4	444	8	445	6	446	16.6.2	447	2	448	6.4	449	6	450	7
451	4.3	452	8.7	453	2.4	454	8	455	7.6	456	4.6.5	457	3.2	458	6.4	459	8.7.6	460	7
461	3	462	7	463	2.4	464	8	465	6	466	2.5	467	2	468	6.4	469	6	470	7
471	3	472	7	473	3.4	474	8	475	7.6	476	2.4.5	477	2	478	4	479	4.6	480	7
481	3	482	7	483	3.5.4	484	8	485	6	486	4.5	487	2	488	4	489	4.5.4.5.6	490	8.7
491	3	492	7	493	5.4	494	8	495	6	496	2.5	497	2	498	4	499	6	500	8.7
501	3	502	8.7	503	6.5.4	504	8	505	7.5.6	506	2.5	507	2	508	6.4	509	7.6	510	7
511	3	512	8.7	513	2.5.6.4	514	8	515	7.6	516	2.5	517	2	518	5.6.4	519	8.7.6	520	7
521	3	522	6.7	523	4	524	8	525	6	526	2.4.5	527	2	528	6.5.4	529	6	530	8.7
531	3	532	7	533	4	534	8	535	7.6	536	5	537	2	538	6.5.4	539	7.6	540	7
541	3	542	8.7	543	4	544	8	545	7.6	546	2.5	547	2	548	6.5.4	549	8.6	550	7
551	4.3	552	8.7	553	6.4	554	8	555	7.6	556	7.4.5	557	2	558	5.4	559	6	560	7
561	4.3	562	8.7	563	4	564	8	565	6	566	5	567	2	568	6.5.4	569	7.6	570	7
571	3	572	8.7	573	4	574	8	575	6	576	4.5	577	2	578	4	579	7.6	580	7
581	3	582	7	583	6.5.4	584	8	585	7.6	586	6.5	587	2	588	6.5.4	589	7.6	590	7
591	3	592	6.7	593	4	594	7.7.8	595	5.6	596	2.3.4.5	597	2	598	3.5.4	599	5.6	600	7



TABLE 9—Continued  
RESULTS FOR FEMALE IN PROBLEM 4

T.	S.1 2.3.4	T.	S.2 5.6.7.8.9	T.	S.3 3.4.5.6.7	T.	S.4 7.8.9	T.	S.5 4.5.6.7.8	T.	S.6 1.2.3.4.5	T.	S.7 1.2.3	T.	S.8 2.3.4.5.6	T.	S.9 4.5.6	T.	S.10 6.7.8
1	3	2	7	3	4.5	4	7.8	5	6	6	2.4.3	7	2	8	4	9	5	10	7
11	3	12	7	13	6.5	14	8	15	6	16	5.4.2	17	2	18	4	19	6.5	20	7
21	3	22	8.7	23	4.5	24	8	25	6	26	2.4.5.2	27	2	28	4	29	5	30	7
31	3	32	7	33	7.6.5	34	8	35	7.6	36	4.5.4.3	37	2	38	5.4	39	5	40	7
41	3	42	7	43	6.5	44	7.8	45	7.6	46	2.4.3	47	2	48	4	49	5	50	7
51	3	52	6.7	53	4.5	54	8	55	6	56	4.5.4.2.3	57	2	58	5.6.4	59	6.5	60	7
61	3	62	7	63	4.5	64	8	65	6	66	2.4.3	67	2	68	5.4	69	6.5	70	8.7
71	3	72	7	73	4.5	74	7.8	75	6	76	4.2.3	77	2	78	4	79	6.5	80	8.6.7
81	3	82	7	83	4.6.5	84	7.8	85	5.4.6	86	2.4.3	87	2	88	4	89	6.5	90	7
91	3	92	7	93	6.5	94	8	95	4.6	96	2.3	97	2	98	4	99	5	100	7
101	3	102	7	103	6.5	104	8	105	6	106	2.4.5.2.3	107	3.2	108	4	109	6.5	110	8.7
111	3	112	7	113	6.5	114	8	115	6	116	2.4.3	117	2	118	5.4	119	5	120	8.7
121	3	122	8.7	123	5	124	8	125	6	126	4.3	127	2	128	4	129	6.5	130	7
131	3	132	7	133	6.5	134	7.8	135	6	136	4.3	137	2	138	6.5.4	139	6.5	140	7
141	4.3	142	7	143	6.5	144	8	145	6	146	2.4.5.3	147	2	148	5.4	149	6.5	150	7
151	3	152	7	153	5	154	8	155	7.6	156	4.3	157	2	158	5.6.4	159	6.5	160	8.7
161	3	162	7	163	6.5	164	8	165	6	166	4.3	167	3.2	168	5.4	169	5	170	8.7
171	3	172	7	173	5	174	8	175	6	176	2.3	177	2	178	4	179	5	180	7
181	3	182	7	183	6.5	184	8	185	6	186	2.4.3	187	2	188	4	189	4.6.5	190	8.7
191	3	192	6.5.8.7	193	4.3.5	194	8	195	6	196	3	197	2	198	6.3.4	199	5	200	7
201	3	202	8.7	203	6.4.5	204	8	205	6	206	4.3	207	2	208	5.4	209	6.5	210	7

TABLE 10  
RESULTS FOR MALE IN PROBLEM 4

T.	S.1 2.3.4	S.2 5.6.7.8.9	S.3 1.2.3.4 5.6.7	S.4 7.8.9	S.5 T. 4.5.6.7.8	S.6 1.2.3.4.5 6.7.8.9	S.7 T. 1.2.3	S.8 T. 2.3.4.5.6	S.9 3.4.5.6 7.8.9	S.10 T. 6.7.8
1	2.4.2.4.3	2	1.7.1.7.4	4	5 {4.8.7.8 4.8.4.7 4.8.5.7 4.8.5.8 6}	6 {1.9.2 8.6.5}	7	8	9 {3.9.5.8 13.9.6}	10 7
11	2.4.3	12	1.6.5.7 2.3.5 1.7.4	14	15	16	17	18	19	20
21	2.3	22	5.1.4	24	25	26	27	28	29	30
31	2.4.3	32	5.1.6.4	34	35	36	37	38	39	40
41	2.3	42	4	44	45	46	47	48	49	50
51	2.3	52	1.7.4	54	55	56	57	58	59	60
61	3	62	5.2.1.6 5.7.3.4	64	65	66	67	68	69	70
71	3	72	6.5.2.4	74	75	76	77	78	79	80
81	4.3	82	2.4	84	85	86	87	88	89	90
91	2.4.3	92	6.2.4	94	95	96	97	98	99	100
101	2.4.3	102	1.3	104	105	106	107	108	109	110
111	3	112	5.6.2.7.4	114	115	116	117	118	119	120
121	3	122	2.4	124	125	126	127	128	129	130
131	3	132	2.4	134	135	136	137	138	139	140
141	4.2.3	142	2.5.7.6.4	144	145	146	147	148	149	150
151	2.4.3	152	1.6.4	154	155	156	157	158	159	160
161	2.4.3	162	2.4	164	165	166	167	168	169	170
171	3	172	7.6.5 6.2.4	174	175	176	177	178	179	180
181	3	182	5.2.4	184	185	186	187	188	189	190
191	3	192	2.4	194	195	196	197	198	199	200
201	3	202	2.4	204	205	206	207	208	209	210
211	2.4.3	212	2.5.7.4	214	215	216	217	218	219	220
221	3	222	2.4	224	225	226	227	228	229	230
231	3	232	2.4	234	235	236	237	238	239	240

TABLE 10  
RESULTS FOR MALE IN PROBLEM 4

T.	S. 1 2.3.4	S. 2 5.6.7.8.9	S. 3 1.2.3.4 5.6.7	S. 4 7.8.9	S. 5 4.5.6.7.8	S. 6 1.2.3.4.5 6.7.8.9	S. 7 1.2.3	S. 8 2.3.4.5.6	S. 9 3.4.5.6 7.8.9	S. 10 6.7.8
231	3	232	233	234	235	236	237	238	239	240
241	3	242	243	244	245	246	247	248	249	250
251	3	252	253	254	255	256	257	258	259	260
261	3	262	263	264	265	266	267	268	269	270
271	2.4.3	272	273	274	275	276	277	278	279	280
281	3	282	283	284	285	286	287	288	289	290
291	3	292	293	294	295	296	297	298	299	300
301	3	302	303	304	305	306	307	308	309	310
311	3	312	313	314	315	316	317	318	319	320
321	3	322	323	324	325	326	327	328	329	330
331	3	332	333	334	335	336	337	338	339	340
341	2.4.3	342	343	344	345	346	347	348	349	350
351	3	352	353	354	355	356	357	358	359	360
361	3	362	363	364	365	366	367	368	369	370
371	3	372	373	374	375	376	377	378	379	380
381	3	382	383	384	385	386	387	388	389	390
391	2.4.3	392	393	394	395	396	397	398	399	400
401	2.3	402	403	404	405	406	407	408	409	410
411	3	412	413	414	415	416	417	418	419	420
421	3	422	423	424	425	426	427	428	429	430
431	3	432	433	434	435	436	437	438	439	440
441	2.4.3	442	443	444	445	446	447	448	449	450
451	2.4.3	452	453	454	455	456	457	458	459	460
461	3	462	463	464	465	466	467	468	469	470
471	3	472	473	474	475	476	477	478	479	480
481	3	482	483	484	485	486	487	488	489	490
491	3	492	493	494	495	496	497	498	499	500
501	3	502	503	504	505	506	507	508	509	510
511	3	512	513	514	515	516	517	518	519	520
521	3	522	523	524	525	526	527	528	529	530
531	3	532	533	534	535	536	537	538	539	540
541	3	542	543	544	545	546	547	548	549	550
551	3	552	553	554	555	556	557	558	559	560
561	3	562	563	564	565	566	567	568	569	570
571	3	572	573	574	575	576	577	578	579	580
581	3	582	583	584	585	586	587	588	589	590
591	3	592	593	594	595	596	597	598	599	600

TABLE 10—Continued  
RESULTS FOR MALE IN PROBLEM 4

T.	S. 1 2.3.4	T.	S. 2 5.6.7.8.9	T.	S. 3 3.4.5.6.7	T.	S. 4 7.8.9	T.	S. 5 4.5.6.7.8	T.	S. 6 1.2.3.4.5	T.	S. 7 1.2.3	T.	S. 8 2.3.4.5.6	T.	S. 9 4.5.6	T.	S. 10 6.7.8
1	3	2	8.7	4	6.4.5	3	7.8	5	6	6	2.4.2.5.3	7	2	8	5.4	9	6.5	10	7
11	3	12	7	14	6.5	13	8	15	6	16	{2.4.5 2.4.3	17	2	18	4	19	6.6.5	20	8.7
21	3	22	8.7	24	6.5	23	8	25	6	26	2.4.3.3	27	2	28	4	29	6.5	30	7
31	3	32	7	34	6.4.5	33	7.8	35	6	36	2.4.5.2.3	37	2	38	6.4	39	6.5	40	7
41	3	42	8.7	44	6.5	43	8	45	6	46	{4.4.5 2.4.3	47	2	48	4	49	4.5	50	7
51	3	52	6.7	54	6.4.5	53	8	55	6	56	4.5.3	57	2	58	4	59	5	60	6.7
61	3	62	7	64	4.5	63	7.8	65	6	66	4.3	67	2	68	4	69	5	70	7
71	3	72	7	74	4.5	73	8	75	4.5.6	76	2.4.3	77	2	78	4	79	4.5	80	6.7
81	2.4.3	82	6.5.6.7	84	4.5	83	7.8	85	6	86	2.4.3	87	2	88	4	89	6.5	90	7
91	2.4.3	92	7	94	4.5	93	7.8	95	4.5.6	96	4.3	97	2	98	4	99	4.5	100	7
101	2.4.3	102	6.5.7	104	5	103	8	105	7.6	106	4.5.3	107	2	108	4	109	5	110	8.7
111	3	112	7	114	5	113	8	115	6	116	2.3	117	2	118	6.4	119	5	120	8.7
121	3	122	8.7	124	6.4.5	123	8	125	6	126	4.2.3	127	2	128	5.6.4	129	6.5	130	7
131	3	132	7	134	5	133	8	135	6	136	4.2.3	137	2	138	3.4	139	5	140	7
141	3	142	7	144	5	143	8	145	6	146	4.2.3	147	2	148	4	149	5	150	7
151	3	152	8.7	154	4.5	153	8	155	4.5.6	156	4.5.3	157	2	158	4	159	5	160	7
161	3	162	7	164	5	163	8	165	6	166	2.4.3	167	2	168	4	169	5	170	7
171	3	172	7	174	5	173	8	175	6	176	2.4.3	177	2	178	4	179	5	180	7
181	3	182	7	184	6.4.5	183	7.8	185	6	186	2.3	187	2	188	4	189	6.5	190	7
191	3	192	7	194	6.5	193	8	195	5.6	196	3	197	2	198	6.5.6.4.3	199	6.5	200	7
201	3	202	7	204	5	203	8	205	6	206	2.3	207	2	208	4	209	6.5	210	7



TABLE 11  
DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
FIRST CHOICES

Female						Male							
PROBLEM 4													
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
Aug. 4	1-0	0	5				Aug. 4	1-0	0	5			
" 6	0-6	0	5				" 6	1-4	1	4			
" 11	4-6	4	6	4	16	1:4.00	" 11	3-7	4	16	4	16	1:4.00
5 21	2-8	2	8				5 21	2-8	2	8			
" 31	3-7	3	7	5	15	1:3.00	" 31	2-8	4	16	4	16	1:4.00
6 41	3-7	3	7				6 41	4-6	4	6			
" 51	4-6	4	6	7	13	1:1.86	" 51	4-6	8	12	8	12	1:1.50
7 61	2-8	2	8				7 61	2-8	2	8			
" 71	4-6	4	6	6	14	1:2.33	" 71	3-7	5	15	5	15	1:3.00
8 81	4-6	4	6				8 81	4-6	4	6			
" 91	2-8	2	8				" 91	5-5	5	5			
" 101	2-8	2	8	8	22	1:2.75	" 101	5-5	5	5	14	16	1:1.14
9 111	3-7	3	7				9 111	3-7	3	7			
" 121	4-6	4	6				" 121	3-7	3	7			
" 131	8-2	2	15	15	1:1		" 131	4-6	6	10	20	1:2.00	
10 141	3-7	3	7				10 141	4-6	4	6			
" 151	4-6	4	6				" 151	3-7	3	7			
" 161	6-4	4	13	17	1:1.31		" 161	3-7	7	10	20	1:2.00	
11 171	5-5	5	5				11 171	5-5	5	5			
" 181	3-7	3	7				" 181	4-6	4	6			
" 191	4-6	4	6	12	18	1:1.50	" 191	6-4	6	15	15	1:1	
12 201	5-5	5	5				12 201	5-5	5	5			
" 211	3-7	3	7				" 211	3-7	3	7			
" 221	5-5	5	13	17	1:1.31		" 221	4-6	6	12	18	1:1.50	
13 231	8-2	2					13 231	4-6	6				
" 241	3-7	3	7				" 241	5-5	5				
" 251	4-6	4	15	15	1:1		" 251	5-5	5	14	16	1:1.14	
14 261	8-2	2					14 261	5-5	5				
" 271	4-6	4					" 271	3-7	3	7			
" 281	6-4	4	18	12	1: .67		" 281	4-6	6	12	18	1:1.50	
15 291	3-7	3	7				15 291	5-5	5	5			
" 301	3-7	3	7				" 301	5-5	5	5			
" 311	3-7	3	7	9	21	1:2.33	" 311	3-7	7	13	17	1:1.31	
16 321	3-7	3	7				16 321	3-7	3	7			
" 331	6-4	4					" 331	6-4	4				
" 341	4-6	4	13	17	1:1.31		" 341	2-8	8	11	19	1:1.73	
17 351	4-6	4	6				17 351	3-7	3				
" 361	4-6	4	6				" 361	5-5	5				
" 371	4-6	4	12	18	1:1.50		" 371	7-3	3	15	15	1:1	
18 381	5-5	5	5				18 381	5-5	5				
" 391	5-5	5					" 391	4-6	4				
" 401	7-3	3	17	13	1: .76		" 401	3-7	7	12	18	1:1.50	
19 411	6-4	4					19 411	6-4	4				

TABLE 11—*Continued*  
DAILY SERIES AND AVERAGES WITH RATIOS OF CORRECT TO INCORRECT  
FIRST CHOICES

Female							Male						
Date	No. of trials	R	W	R	W	Ratio of R to W	Date	No. of trials	R	W	R	W	Ratio of R to W
Aug.							Aug.						
"	421-	7	3				"	421-	6	4			
"	431-	4	6	17	13	1: .76	"	431-	5	5	17	13	1: .76
20	441-	6	4				20	441-	4	6			
"	451-	2	8				"	451-	4	6			
"	461-	7	3	15	15	1:1	"	461-	7	3	15	15	1:1
21	471-	6	4				21	471-	5	5			
"	481-	6	4	12	8	1: .67	"	481-	7	3	12	8	1: .67
22	491-	7	3				22	491-	5	5			
"	501-	4	6				"	501-	4	6			
"	511-	4	6	15	15	1:1	"	511-	7	3	16	14	1: .88
23	521-	6	4				23	521-	6	4			
"	531-	7	3				"	531-	6	4			
"	541-	5	5	18	12	1: .67	"	541-	7	3	19	11	1: .58
24	551-	4	6				24	551-	5	5			
"	561-	6	4				"	561-	7	3			
"	571-	7	3	17	13	1: .76	"	571-	8	2	20	10	1: .50
25	581-	5	5				25	581-	4	6			
"	591-	4	6	9	11	1:1.22	"	591-	7	3	11	9	1: .82
25	1-	7	3	7	3	1: .43	25	1-	4	6	4	6	1:1.50
26	11-	7	3				26	11-	6	4			
"	21-	7	3				"	21-	6	4			
"	31-	6	4	20	10	1: .50	"	31-	5	5	17	13	1: .76
27	41-	6	4				27	41-	6	4			
"	51-	5	5				"	51-	6	4			
"	61-	5	5	16	14	1: .88	"	61-	7	3	19	11	1: .58
28	71-	5	5	5	5	1:1	28	71-	5	5	5	5	1:1
30	81-	5	5				30	81-	4	6			
"	91-	7	3				"	91-	4	6			
"	101-	5	5	17	13	1: .76	"	101-	5	5	13	17	1:1.31
31	111-	6	4				31	111-	7	3			
"	121-	7	3				"	121-	5	5			
"	131-	5	5	18	12	1: .67	"	131-	8	2	20	10	1: .50
Sept.							Sept.						
1	141-	5	5				1	141-	9	1			
"	151-	5	5				"	151-	6	4			
"	161-	5	5	15	15	1:1	"	161-	9	1	24	6	1: .25
2	171-	9	1				2	171-	9	1			
"	181-	6	4				"	181-	7	3			
"	191-	7	3	22	8	1: .36	"	191-	6	4	22	8	1: .36
3	201-	5	5	5	5	1:1	3	201-	8	2	8	2	1: .25

After six hundred trials had been given to each individual by use of the series of settings presented on page 192, under problem 4, it was apparent that the animals could succeed in solving the problem only by acquiring a definite habit for each particular setting, and it was further evident that the settings including seven and nine open doors were extremely difficult for the animals. For these reasons it was decided to present a modified series of settings in which the groups should consist of either three or five open doors. Two hundred trials were given with the new series of settings, and the settings themselves, as well as the results obtained, appear at the bottom of tables 9 and 10.

Two important conclusions are justified by these results. First, that the pigs, in so far as they had succeeded in responding correctly to the middle door, had reacted to particular settings. And second, that with sufficiently prolonged training they could perfectly solve the problem of the middle member of a series, if the total number in a group of open doors did not exceed five. As a matter of fact, no series of ten correct choices was obtained with either individual because of the surprisingly strong and persistent influence of the original settings.

Let us consider, for example, setting 3. This originally consisted of the group 1.2.3.4.5.6.7, in which no. 4 was the box to be entered. In the modified settings, this group was changed to 3.4.5.6.7, consequently, the box to be entered was 5 instead of 4. Now, whereas in the case of setting 1 which remained unchanged, the female made only one mistake in twenty-one trials subsequent to the modification of the settings, in the case of setting 3 she chose wrongly in all except three of the twenty-one trials, and this in spite of the fact that in the case of settings 2 and 5, both of which involved five open doors, she chose correctly sixteen times out of twenty-one. Similarly in the case of setting 6, in which originally all nine of the doors were open, whereas in the modification only doors 1, 2, 3, 4 and 5 were used, both the female and the male chose correctly only once in twenty-one trials.

Although the above conclusions are of primary importance, further examination of the data of tables 9 and 10 should throw additional light on the reactive capacity of our subjects.

We shall consider the materials according to the number of

mechanisms used in the settings. Settings 1, 4, 7 and 10 involve three members, setting 2, 5 and 8, five members; settings 3 and 9, seven members; and setting 6, nine members. Below are presented the number of correct first choices made by each individual in connection with each setting, the total number of choices being sixty.

Correct First Choices *in Sixty* for Each Setting in Problem 4

	S.1	S.2	S.3	S.4	S.5	S.6	S.7	S.8	S.9	S.10
Female.....	35	22	16	45	22	10	49	11	22	38
Male	41	21	4	48	27	12	52	11	19	34

These figures prove that to select the middle member of a group of three is fairly easy for the pig. This, to be sure, might be gathered from the fact that the animal can solve the problem of the second from the left. It further appears that attempts to locate the proper box when it was the middle of a series of five resulted in a gradual reduction in the number of incorrect choices, but never yielded success. The selection of the middle member of a group of seven or of nine is clearly still more difficult, and there is no reason to suppose that with less than thousands of trials the subjects in question would have learned to enter it directly.

It is practically certain that the series of settings rather than the number of members in a group is responsible for the animal's confusion. Doubtless by training a pig to react correctly to each setting and by then presenting the several settings in a certain definite order, a habit could be built up which would apparently yield a perfect solution of problem 4. It is, however, needless to point out that this would not be the kind of solution that has been obtained for problems 1, 2 and 3, or in other words, would not be dependent upon response to the general relation middleness.

Analysis of the records for the sixty trials under setting 6 are of special interest, since this setting proved the most baffling of all to the subjects.

To begin with, they naturally tried the end members of the series. This proving unsatisfactory, they next tended to choose rather at random, and then there gradually appeared a tendency to enter, first, box 2 and to proceed thence either directly or



by way of 3, 4 and sometimes also 6, to the middle box, number 5. This tendency to select, when in doubt, a box second from the right end of the series may possibly be due in part to the fact that the box to be chosen in setting 7 was number 2. At any rate, the frequency with which the female throughout her training chose box 2 first of all under setting 6 is surprisingly high, whereas for the male, this frequency while rather high early in the course of the training, tended to diminish and to give place to the decidedly profitable tendency to choose a box near the middle of the series, 6, 7 and 5 frequently being entered.

Similarly, we might, if space permitted, analyse in detail the results for the other settings. We have chosen to use our space in this report for the presentation of data in tabular form rather than for their description, because we are convinced that the facts are more important than early attempts at interpretation.

#### SUMMARY

1. The pig has proved itself an ideal subject for studies in adaptive behavior.

2. The new multiple choice method, by means of which standardized problems ranging in difficultness from the very easy to the very difficult may be presented to widely differing types of organism, has in our opinion fully justified our expectations, for it has proved admirably suited to the discovery and analysis of increasingly complex types of behavior.

3. For the purpose of discovering the extent to which ideational and closely allied types of behavior exist in the pig, four problems were presented. They may be defined simply in terms of the constant relation of the right mechanism, as (1) the first at the right end of the series; (2) the second from the left end of the series; (3) alternately, the first at the left and the first at the right; (4) the middle member of the series.

The purpose of the experiments was to discover the pig's reactive tendencies and especially its degree of ability to disassociate the essential and constant relation of the right mechanism from its accidental and variable accompaniments.

4. The two subjects solved perfectly the first problem with less than fifty experiences. The indications are that visual and kinaesthetic guidance sufficed.

The second problem was solved more slowly, partly because the influence of the earlier training had to be overcome, but

also because this is a much more difficult problem than the first one. In this also, visual and kinaesthetic guidance seems to account for success, but the extent to which the animals learned to respond to the relation of secondness from the left, no matter what the other relations of the mechanism, was a surprise to the experimenters and is important in connection with the problem of ideation in animals.

The third problem also was solved with reasonable ease, and the animals demonstrated their ability to acquire the habit of alternation without respect to particular groups of reaction-mechanisms.

Problem 4 proved too difficult for the pigs. They learned to select the middle mechanism of the series when the groups were small, but when seven or nine mechanisms were in use, they were confused. The indications are that with long training they would learn to react to the particular settings correctly, although incapable of reacting to the constant relation of middleness.

5. Our results indicate for the pig an approach to free ideas which we had not anticipated. There seems no reason to doubt that visual and kinaesthetic factors in the main determine their responses, but it is evident that they are not so dependent upon the particular situation as are many other mammals. While hesitating to claim that we have demonstrated the presence of ideas, we are convinced that the pig closely approaches, if he does not actually attain, to simple ideational behavior.

6. The multiple choice method has revealed a number of interesting reactive tendencies, their relations to one another, and the varied ways in which they are manifested in connection with situations which are rather difficult to meet.

7. Finally, we would again call attention to the fact that this method of studying behavior should enable us, when it has been reasonably perfected and its problems standardized, to determine the level of mental development in different individuals, species, stages of growth, and conditions of normality, and to compare the reactive tendencies, whether or not ideational, of other organisms with those of the human subject. Our results thus far fully convince us that the method may be made to yield more valuable psychological and behavioristic information than has any previous approach to ideational problems.

## HABIT FORMATION IN THE FIDDLER CRAB

BY BENJAMIN SCHWARTZ AND S. R. SAFIR

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Albrecht Bethe (1898) was the first one to investigate associative memory in crustacea. After analyzing the normal behavior of the green crab, *Carcinus moenas*, on the basis of the structure of the nervous system, Bethe endeavored to discover whether the animal could modify its behavior and thus profit by experience. He liberated a crab in an aquarium containing a cephalopod, *Eledone*, in the darkest corner. The crab, following its instinct to hide, ran to that corner and was immediately seized by the squid. At this point the experimenter interfered, and quickly freeing the animal from its captor, placed it again in the lighted portion of the aquarium. The animal ran back to the dark corner and was again seized by the squid. This experiment was repeated five times with one individual and six times with another, without any evidence that the animal learned to avoid the dangerous corner. Bethe then tried another experiment. He baited a crab with a piece of meat and maltreated it every time that it snapped at the bait. This was repeated a number of times, and as in the previous experiment, he found no modification in the animal's reaction to the stimulus. He, therefore, concluded that the activities of *Carcinus* are limited to reflexes and instincts, the animal being incapable of exercising any higher mental faculties.

Yerkes (1902) objects to Bethe's conclusion on two grounds: (1) He maintains that the data is altogether insufficient to warrant any generalization, and (2) that the experiments are of such nature that negative results based on more sufficient data would still be inconclusive proof of the animal's inability to profit by experience. It is evident that Bethe endeavored to suppress two fundamental instincts, namely, fear and hunger. To expect an animal to modify these after five or six experiences is almost preposterous. Yerkes therefore tested the American

form, *Carcinus granulatus*, for habit formation. He constructed a simple labyrinth containing two blind alleys and one opening. In this labyrinth a number of crabs were liberated daily for a period of two weeks, and were given on an average of four trials per day. It was found that the animals gradually learned to avoid the blind alleys, although even fifty experiences in the case of most did not result in a perfect habit. He also found that if the aquarium was divided into two compartments by means of a wire screen, which contained an opening in its center, the animals learned with increasing rapidity to find the opening, in order to get to the food at the opposite side. From these results Yerkes concluded that *Carcinus* possesses associative memory.

Yerkes and Huggins (1903) studied habit formation in the crawfish, *Cambarus affinis*. They constructed a labyrinth containing a triangular chamber at one end, while the opposite end contained one closed and one open corner, the latter leading into an aquarium. The animal was placed in the triangular chamber, and could go to either corner in seeking to escape. For one month, each of three animals was given on an average two trials per day. The records of the movements to the closed and open corners showed an increase from fifty to ninety per cent in the direction which led to escape. A test of habit retention after a rest of two weeks, showed that the association persisted. Their general conclusions are: (1) Crawfish are able to learn a simple labyrinth habit, (2) they profit slowly, fifty to a hundred experiences being necessary for perfect association, (3) the chief factors in the habit forming process are smell, touch, sight, and muscular activity, (4) if the possibility of scent is excluded by washing the box after each trial, the animals are still capable of learning.

Other investigators working with different forms have confirmed Yerkes' conclusions. Spaulding (1904) found that the hermit crab, *Eupagurus longicarpus*, which is positively phototactic, could learn to go to a shaded portion of an aquarium for food. The association became so perfect, that the mere introduction of the screen, in order to divide the aquarium into two compartments, caused the animals to run to the shaded half. Drzewina (1908) observed that *Pachygraspus marmoratus*, which is negatively phototactic during the day, reacts positively



to light at night. Taking advantage of this tropism, she succeeded in making the crabs come from the shaded side of the box to the side which was artificially illuminated, although in doing this, the animals had to find an opening in the partition which divided the box. The rapidity with which the opening was found increased with successive trials. The same writer\* (1910) studied habit formation in the hermit crab, *Clibanarius misanthropus*. She placed tightly corked gastropod shells near naked crabs. The latter immediately fastened themselves upon the shells, trying to pull out the corks. Since all their efforts to enter the shells were in vain, the animals were observed to relax, and at the end of from six to eight days, they became entirely indifferent to their presence. If at this point of the experiment, shells, similarly sealed but of different shape, were introduced, the crabs began to attack them immediately. These results indicate that *Clibanarius* not only possesses associative memory but that it is also able to discriminate form. Cowles (1908) found that *Ocypoda arenaria* could learn to escape from a labyrinth, although it did not learn the position of the exit very accurately. He also found that if he buried a dish of salt water in the sand of their trap, so that the rim of the dish was on a level with the surface of the sand, the crabs learned to climb into the vessel to moisten their gills.

The experiments described hereafter were performed with the fiddler crabs which inhabit the sand spit at Cold Spring Harbor, Long Island. They live on sandy beaches as well as on mud flats, where they construct burrows about one foot in depth. They are diurnal in their habits, and on bright, sunny days they may be seen in large numbers, running hither and thither, feeding and burrowing. The males are particularly striking because of the large cheliped with which they perform curious antics, and which they use as a weapon for combat. When the tide comes in the crabs retreat to their burrows, where they remain until the area above them is again exposed by the receding waters. Their general activities are therefore interrupted at regular intervals, during which they remain perfectly quiet. Their behavior appears to be regular and unchanging, almost stereotyped.

There are two species of fiddler crabs on the sand spit, *Uca*

\*This paper was not available to us. We read an abstract of it in *The Jour. of An. Beh.*, Vol. 1, No. 6, pp 450-451, 1911.

*pugnax* and *Uca pugilator*, the most distinguishing characteristic of the latter being a ridge across the palm of the large cheliped. In the experiments the pugilators were utilized almost exclusively, because of their greater vigor and resistance. The *pugnax* forms did not thrive in captivity, and became very sluggish. The work with them could not progress very rapidly.

The aim of the experiments was to determine (1) whether the fiddler crabs can form a simple labyrinth habit, (2) whether the habit is retained for a few days, and (3) whether the habit can be broken up.

When the crabs are placed in a wooden box which is about one-half full of moist sand or mud, they immediately begin to seek a means of escape. They usually run to the side opposite which the experimenter is standing, and climb up the sides, near the corners, by inserting the sharply pointed ends of their ambulatory feet into the rough surfaces of the wood. They climb gradually and do not seem to become discouraged by failures. As soon as they reach the top of the box, they escape. It was observed that the animals showed a decided tendency to go to a particular corner, even though escape was rendered impossible by inserting glass plates against the sides. Table 1 gives the records of twelve individuals, showing the corner to which they went, as well as the average interval between two successive trials.

TABLE 1

Individual	No. of trials	Time	Average interval	Corner			
				1	2	3	4
1	25	30 min.	1 min. 12 sec.	1	21	0	3
2	25	44 "	1 " 47 "	3	19	1	2
3	20	27 "	1 " 22 "	4	15	0	1
4	20	30 "	1 " 30 "	0	9	0	11
5	20	28 "	1 " 24 "	14	6	0	0
6	20	37 "	1 " 49 "	15	1	4	0
7	20	54 "	2 " 42 "	11	8	0	1
8	20	24 "	1 " 12 "	2	18	0	0
9	20	53 "	2 " 40 "	4	12	3	1
10	30	30 "	1 " 0 "	3	4	22	1
11	18	31 "	1 " 43 "	0	5	13	0
12	35	45 "	1 " 17 "	30	10	3	2

An examination of the above table shows (1) that the interval between two successive trials varies from about one and a half to two minutes, (2) that the animal's desire to liberate itself from the trap persists even when thirty-five trials are given,

(3) that each animal chooses one particular corner from which to escape. The last fact is of the utmost importance, because the labyrinth habit with the fiddler crab involves not only a process of learning, but also the overcoming of a strong inclination. By closing the corner to which the animal is inclined to go, the experimenter is in a position to determine whether the animal can modify its behavior.

TABLE 2

RIGHT HANDED MALES			LEFT HANDED MALES			FEMALES			
No.	Right	Left	No.	Right	Left	No.	Right	Left	Center
1	7	3	1	1	9	1	3	3	4
2	5	5	2	1	9	2	4	5	1
3	7	3	3	2	8	3	4	2	4
4	10	0	4	10	0	4	1	3	6
5	0	10	5	0	10	5	2	1	7
6	7	3	6	0	10	6	2	3	5
7	7	3	7	6	4	7	3	2	5
8	0	10	8	7	3	8	3	3	4
9	1	9	9	3	7	9	2	3	5
10	0	10	10	6	4	10	4	0	6
11	7	3	11	8	2	11	5	2	3
12	7	3	12	2	8	12	1	6	3
13	6	4	13	5	5	13	7	1	2
14	7	3	14	5	5	14	5	3	2
15	9	1	15	5	5	15	1	8	1
16	5	5	16	5	5	16	1	7	2
17	7	3	17	3	7	17	3	5	2
18	5	5	18	2	8	18	4	3	3
19	6	4	19	2	8	19	3	3	4
20	6	4	20	2	8	20	2	2	6
21	7	3	21	0	10	21	4	0	6
22	7	3	22	2	8	22	1	2	7
23	8	2	23	0	10	23	5	2	3
24	5	5	24	2	8	24	6	2	2
25	4	6	25	2	8	25	5	3	2
26	9	1	26	3	7	26	2	5	3
27	9	1	27	8	2	27	1	8	1
28	7	3	28	7	3	28	6	1	3
29	10	0	29	2	8	29	4	2	4
30	9	1	30	4	6	30	5	2	3
31	9	1	31	1	9	31	1	7	2
32	10	0	32	2	8	32	3	3	4
33	8	2	33	8	2	33	3	5	2
34	7	3	34	4	6	34	5	2	3
35	8	2	35	2	8	35	3	4	3
226		124	122		228	114		113	123

The reasons for the individual preferences were by no means evident. Since the animals exhibit a positive phototaxis it was at first supposed that this peculiar reaction was caused by

light, but it was found that when the latter was eliminated, the preference was not changed. Hence some other explanation had to be sought. An examination of the male crab shows it to be unsymmetrical, owing to the possession of the large cheliped, which may be either on the right or the left side of the body. This suggested the hypothesis that the right handed males are inclined to go to the right side, and the left handed males to the left side. Since the females possess no large cheliped, they were expected to be neutral in this respect. That these expectations were fairly borne out may be seen in table 2.

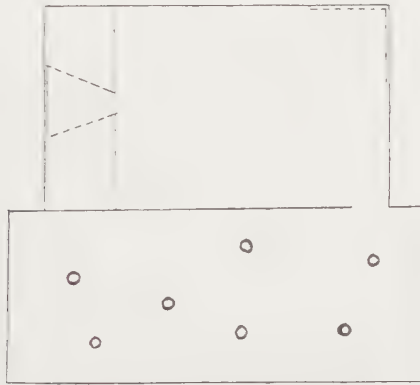


FIG. 1. Showing labyrinth and adjoining box. Dotted lines represent glass plates, and circles represent burrows.

An examination of the data presented above shows that 70% of the males made a majority of their movements to the corner corresponding to the position of their cheliped. About 10% showed no preference for either side, while the remainder, about 20%, went to the side directly opposite to the expectation. But the fact remains that about 90% are inclined to go to a particular side. The number of trials for the right handed males is 226 to the right and 124 to the left, giving a ratio of about 2:1, that of the left handed males is 228 to the left and 122 to the right, giving a similar ratio. The females made 114 attempts to the right, 113 to the left, and 123 to the center, giving a ratio of 1:1:1. By an attempt to the center is meant a direct movement from one end of the box to the center of the opposite end,



where the animal pauses for about five seconds before going to either corner.

With these facts before us, we subjected ten animals, seven males and three females, picked up at random, to a simple labyrinth test. Our labyrinth was modelled after the one described by Yerkes and Huggins, with modifications adapted to the needs of the fiddler crabs. We selected a box 50 cm. long, 30 cm. wide, and 30 cm. deep. It was filled to a depth of 12 cm. with moist sand, in order to give the animals a natural substratum. By means of glass plates, 12 cm. square, we made a triangular space at the center of one of the narrower ends, with an opening sufficiently large to enable the crabs to pass through. At the corners of the opposite end we cut out openings, 8 cm. wide and 5 cm. high, which could be closed by means of glass plates. To prevent the animals from going to the corners of that end of the box which contained the triangular chamber, we placed glass plates extending at right angles from each side of the opening of the chamber to the long side of the box. Adjoining the labyrinth there was another box, 60 cm. long, 25 cm. wide and 25 cm. deep. It was filled with moist sand to a depth of 12 cm, several artificial burrows being made in the sand. By means of an opening at each end of the longer side, the box could be made to communicate with the labyrinth on either side.

At first both corners of the labyrinth were closed by means of glass plates and each of the animals to be tested was given a series of preliminary trials to determine to which side of the box it was inclined to go. As soon as this was determined, the favorite corner was left closed, while the one opposite was opened. The crab was then placed in the chamber by the experimenter, who took up his position three feet behind the box, remaining perfectly quiet. His position afforded him a good view of the animal's movements, which were carefully noted. As soon as the crab was liberated it made a number of efforts to climb up the sides of the glass chamber. In doing this it fell after each attempt, the shock evidently frightening it. It then abandoned climbing, and either ran out of the enclosure very rapidly, or moved out rather cautiously, going to its favorite corner. Here, too, it made attempts to climb, but making no headway against the smooth surface of the

glass, it began to move to the opposite corner. In the beginning the animal would go half way and turn back, trying to climb again. Finally it would venture all the way across, run out through the opening into the adjoining box, and enter one of the burrows. If an individual showed too much stubbornness, by remaining at the closed corner even after it had given up its climbing, the experimenter gently drove it in the direction of the open corner. The crab was allowed to remain in this burrow for about a minute, after which it was taken out and again placed in the triangular chamber, the experimenter taking up the same position as before. It usually took the animal about one minute to recover its composure before making a second trial. With successive trials it seemed to learn that there was one corner which afforded an exit, for no sooner than it reached the closed side, it reversed its direction, and liberated itself from the trap. Sometimes a crab would start off in the direction of the closed corner, but before reaching it, would turn and go to the open. Occasionally an animal ran directly to the center and remained there for a few seconds, often running first in one direction and then in another, before making its final choice. Gradually movements to the open corner became more frequent, attaining almost perfection at the end of ten days, with an average of twenty trials per day.

Following, in table 3, are the records of ten\* individuals:

TABLE 3

No. 1. <i>U. pugilator</i> , female					No. 2. <i>U. pugilator</i> , male, left handed				
Day	Closed	Open	% Closed	% Open	Day	Closed	Open	% Closed	% Open
1	18	2	90	10	1	18	2	90	10
2	15	5	75	25	2	16	4	80	20
3	12	8	60	40	3	15	5	75	25
4	10	10	50	50	4	18	2	90	10
5	10	10	50	50	5	14	6	70	30
6	8	12	40	60	6	10	10	50	50
7	9	11	45	55	7	3	17	15	85
8	7	13	35	65	8	10	10	50	50
9	6	14	30	70	9	3	17	15	85
10	1	19	5	95	10	3	17	15	85

\* Nos 1, 2, 3, 4 and 10 were experimented with at Cold Spring Harbor. The remaining five were tried at Hunter's Island, New York City.

No. 3. *U. pugilator*, male, right handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	14	6	70	30
2	5	15	25	75
3	4	16	20	80
4	3	17	15	85
5	4	16	20	80
6	1	19	5	95
7	1	19	5	95
8	0	20	0	100
9	1	19	5	95
10	0	20	0	100

No. 5. *U. pugilator*, left handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	18	2	90	10
2	15	5	75	25
3	10	10	50	50
4	7	13	35	65
5	9	11	45	55
6	10	10	50	50
7	5	15	25	75
8	4	16	20	80
9	1	19	5	95
10	4	16	20	80

No. 7.\* *U. pugilator*, left handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	15	5	75	25
2	9	11	45	55
3	8	12	40	60
4	7	13	35	65
5	5	15	25	75
6	4	16	20	80
7	3	17	15	85
8	3	17	15	85
9	2	18	10	90

\* Died.

No. 9. *U. pugilator*, female

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	12	8	60	40
2	5	15	25	75
3	8	12	40	60
4	3	17	15	85
5	5	15	25	75
6	4	16	20	80
7	6	14	30	70
8	4	16	20	80
9	2	18	10	90
10	5	15	25	75

No. 4. *U. pugnax*, right handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	13	7	65	35
2	8	12	40	60
3	9	11	45	55
4	2	18	10	90
5	4	16	20	80
6	3	17	15	85
7	4	16	20	80
8	4	16	20	80
9	2	18	10	90
10	3	17	15	85

No. 6.\* *U. pugilator*, left handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	15	5	75	25
2	8	12	40	60
3	12	8	60	40
4	10	10	50	50
5	10	10	50	50
6	11	9	55	45
7	9	11	45	55

\* This animal died at the end of seven days.

No. 8.\* *U. pugilator*, female

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	12	8	60	40
2	9	11	45	55
3	6	14	30	70
4	6	14	30	70
5	7	13	35	65
6	7	13	35	65
7	5	15	25	75

\* Died.

No. 10.\* *U. pugilator*, right handed

Day	Closed	Open	$\frac{C}{O}\%$	$\frac{O}{C}\%$
1	14	6	70	30
2	13	7	65	35
4	13	7	65	35
6	11	9	55	45
9	14	6	70	30
10	11	9	55	45
12	10	10	50	50
14	10	10	50	50
16	9	11	45	55
18	10	10	50	50

\* This crab was tested at irregular intervals.

The individual records presented above are summarized in table 4.

TABLE 4

No.	Open att. 1st day	Open att. last day	% 1st day	% last day	% gain	Min. open	Max. open	Min. %	Max. %	% gain	No. of days
1	2	19	10	95	85	2	19	10	95	85	10
2	2	17	10	85	75	2	17	10	85	75	10
3	6	20	30	100	70	6	20	30	100	70	10
4	7	17	35	85	40	7	18	35	85	50	10
5	2	16	10	80	70	2	19	10	95	85	10
6	5	11	25	55	30	5	12	25	60	35	7
7	5	18	25	90	65	5	18	25	90	65	9
8	8	15	40	75	35	8	15	40	75	35	7
9	8	15	40	75	35	8	18	40	90	50	10
10	6	10	30	50	20	6	11	30	55	25	10

Table 4 shows (1) that none of the individuals experimented with ever made fewer open attempts than it made on the first day, (2) that the maximum number of open attempts approximates those of the last day, (3) that the greater the number of days an animal was tried, the greater the gain. Number 10, which was tried at irregular intervals, lasting for a period of eighteen days, gained less than any other individual. To be sure, considerable variation in the rapidity of habit formation is exhibited, some of the crabs made their maximum number of open trials about the sixth day, while others did not succeed in learning the direction of the open corner accurately until the last day. Habit formation, like any other character, is subject to the law of variation, being stronger in some individuals than in others.

It is evident, however, that the fiddler crab can overcome his proclivity for one direction, and learn to go in the opposite one, if the latter enables him to escape from a trap. The mere fact that after encountering the glass obstruction, the animal goes to the open side, is in itself significant. The experimenter was obliged to drive the animal away from the closed end in the very beginning of the experiment. After the first ten attempts, it learned to find the opening by itself. But the ability to overcome its inclination almost entirely, making 90% of its movements in the direction which leads to escape, is unmistakable evidence that the fiddler crab possesses associative memory. To be sure, it learns slowly, perhaps more so than the crawfish, but it should be remembered that the crawfish showed no



preference for any side, whereas the fiddler crab had to overcome a strong inclination. Viewed in this light the gains which the animals made during the 10 days during which they were tried are enormous.

It should be mentioned that the possibility of establishing pathways was obviated by either scraping off the top layer of the substratum, or by adding a fresh one. Sight and touch seemed to be the chief factors in the habit forming process, the former predominating. It was observed that an animal would often begin to go in the direction of the closed end, but before approaching it, would turn and go in the opposite direc-

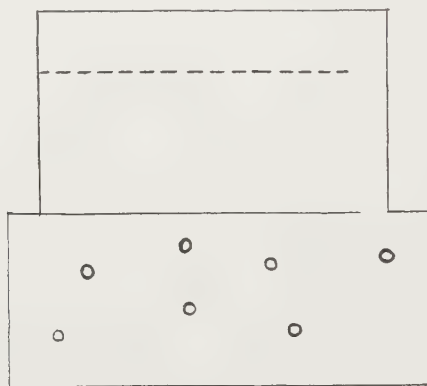


FIG. 2. Showing labyrinth with alley. Dotted line represents glass plates, and circles represent burrows.

tion. This seemed to point to sight as the basic factor in the habit forming process.

In order to test this hypothesis, another type of labyrinth was devised. By means of glass plates, an alley, 10 cm. wide, leading directly to the closed end, was made on one side of the box. The glass plates which formed one side of the alley extended to within a distance of 8 cm. of the end of the box in order that the crab might turn and avoid the blind corner.

Five crabs which had given the best results with the labyrinth test, were made the subjects of the experiment. They were tried for two successive days, being given ten trials per day. Upon being liberated at the end of the alley nearest the experimenter, the crab began to seek a means of escape. If

it did not turn before reaching the end of the alley, it was charged with a closed trial. If it did turn, however, and liberated itself from the alley by going to the open corner, the attempt was recorded open. The results are given in the following table, 5:

TABLE 5

No.	Days	Closed	Open	% Closed	% Open
1	1	2	8	20	80
	2	1	9	10	90
3	1	1	9	10	90
	2	0	10	0	100
4	1	3	7	30	70
	2	1	9	10	90
5	1	2	8	20	80
	2	2	8	20	80
9	1	2	8	20	80
	2	2	8	20	80

From the above data it is evident that the animal was guided by its sense of sight in liberating itself from the alley. It should be borne in mind that the fiddler crab is positively thigmotactic, and under ordinary circumstances it has a strong tendency to follow the sides of the box. The animals which were subjected to this test had already learned to free themselves from the trap, and therefore knew the direction of escape. They were, therefore, able to avoid the side which led to the blind end of the alley.

The crabs were given a rest of ten days, at the end of which they were tested for habit retention. Unfortunately, five of the animals died during the interval, and two of the remaining ones were too sluggish to give results. Those which were tested gave the following records, table 6:

TABLE 6

No.	Closed	Open	% Closed	% Open
1	3	7	30	70
3	1	9	10	90
4	2	8	20	80

These three crabs were now tried for unlearning. The corner which had been closed was opened, and the open one closed. Each animal was tried for five days, being given twenty trials

per day. The reversal of the open corner was at first very confusing to the creature. Upon being liberated in the chamber, it ran to the closed corner, and remained there with greater stubbornness and persistence than had ever been witnessed before. It was almost impossible to drive the animal in any other direction. Sometimes it would venture to the open corner but would abandon it for the closed one. Gradually, however, it learned to escape, although the effect of previous experience had no influence on the rapidity of unlearning. The records are given below:

TABLE 7

Day	Closed	No. 1		% Closed	% Open	Day	Closed	No. 3		% Closed	% Open
		Closed	Open					Closed	Open		
1	17	3		85	15	1	19	1		95	05
2	7	13		35	65	2	13	7		65	35
3	4	16		20	80	3	15	5		75	25
4	4	16		20	80	4	10	10		50	50
5	4	16		20	80	5	5	15		25	75

No. 4

Day	Closed	Open	% Closed	% Open
1	9	1	95	5
2	17	3	85	15
3	10	10	50	50
4	11	9	55	45
5	7	13	35	65

## SUMMARY AND CONCLUSIONS

1. The fiddler crab shows a strong desire to liberate itself from a trap, making on an average of thirty-five attempts an hour.

2. It goes persistently to a certain corner, even though escape is rendered impossible by placing glass obstructions to prevent it from climbing out.

3. The hypothesis that dextrous males are inclined to go to the right side, the sinistrous males to the left side, and females equally to the center and both sides, is fairly well borne out by experimental evidence.

4. Taking advantage of the foregoing tendencies, the fiddler crab may be made to reverse its proclivity, and escape from a labyrinth through an opening at the opposite side.

5. It learns slowly, increasing its movements to the open corner with successive trials.

6. The rapidity of habit formation varies directly with the frequency of the trials.

7. Sight and touch are the most important factors in the habit forming process, the former predominating.

8. An animal which formed the habit can avoid a blind corner by turning before reaching the end of an alley.

9. The habit persists after a lapse of ten days.

10. The crab can unlearn the habit, although previous experience seems to have no influence on the rapidity of unlearning.

In concluding, we wish to express our indebtedness to Dr. H. E. Walter for his reading of the manuscript.

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## THE ABILITY OF THE MUD-DAUBER TO RECOGNIZE HER OWN PREY (HYMEN.)

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### INTRODUCTION

During the summer months two species of mud-dauber are often seen at the edges of streams, filling their mandibles with the soft mud, carrying load after load to some sheltered spot and fashioning it into a many-celled nest. As each cell is completed the wasp provisions it with spiders, usually paralyzed by her sting, cements her egg to one, almost always the last one brought in, and then seals the cell. The egg hatches and the larva spends its time in devouring the spiders while the mother wasp goes on adding cell to cell until the nest grows to great proportions, sometimes as many as thirty-six cells.

Of these two species so commonly seen the steel-blue wasp is *Chalybion caeruleum* and the yellow-legged one *Sceliphron (Pelopoeus) caementarium*. Our observations are almost entirely upon the latter species. The experiments are for the purpose of ascertaining the wasp's ability to distinguish her own prey or to recognize another's spiders, and her attitude toward such.

In 1912<sup>1</sup> we were watching a *Pelopoeus* mother industriously filling her cell with spiders. While she was out foraging we borrowed four fine fresh spiders from another new nest near by and with the forceps carefully inserted them into her cell. Upon her return she was at once aware of the intrusion and set about to carry out the foreign spiders with much indignant buzzing. Nor did she stop at this, but carried out and threw away three of her own hard-earned prey as well, before her indignation had cooled sufficiently to permit her to continue her work. It was quite apparent that she recognized the spiders not of her own capture, but why should she reject them because a sister wasp had caught them, and why should she discard a

<sup>1</sup> *Ent. News*, vol. XXIV, pp. 392-396.



part of her own unless she meant to clear them all out as though they were contaminated? Would other mother wasps act in the same way under similar circumstances? These questions led us on to further experiments the following summer, with many varied and surprising results. The observations were made during a week's vacation, on wasps building in an old barn at Lake View, Kansas. Only the details of each experiment can give the reader a fair idea of their varied behavior.

#### EXPERIMENTS

*Exp. 1.* A new *Pelopoeus* cell was found already one-fourth filled with spiders. When an opportunity occurred, I slyly filled it high with spiders from another nest. The mother wasp returned with a large spider, and spent some time in laboriously cramming it in. Quite satisfied now with her store, she brought balls of mud and duly closed up the cell. But while she was gone for another load I picked open the seal and extracted part of the contents. Arriving at the nest with the next pellet she saw the injury and was alarmed, hurried out and threw the mud away, returned and indignantly carried out the remaining spiders one by one, her own as well as mine, until the nest was quite empty.

*Exp. 2.* While *Pelopoeus* was gone I stirred up the spiders which she had placed in her cell and added one from another nest. When she returned she promptly carried it out, and made four more trips, each time carrying out one of her own capture, until all were gone. Then, after a brief, unexplained absence she came back and inspected the empty cell, fretted and examined and stood guard over it for an hour and a half all because a few spiders had been disturbed.

Upon returning three hours later I found the cell sealed. I opened it and found just two medium-sized spiders, with an egg attached to one. Thus this mother was so anxious about her progeny that she carried out and rejected all of the spiders which had been touched by human hand or forceps, and now she sealed up the egg with only sufficient food to carry it half through its larval life.

*Exp. 3.* One day while collecting nests I removed a large one from a shelf against the barn-wall. No sooner done than a

blue wasp, *Chalybion caeruleum*, returned to it. She examined the spot very carefully for about thirty minutes. When she flew out I replaced the nest, but before doing so I removed five spiders from the new cell which she was engaged in filling. She returned, still with the green spider which she carried when first she missed her nest. She hovered about on the nest very nervously for some minutes and entered the cell five or six times and seemed greatly excited and puzzled; she re-examined the whole nest again and again and re-entered the cell many times, and finally after thus hesitating for about forty minutes she soared away with an indignant buzz, without even depositing her new prey.

While she was gone I removed six spiders from another cell of her own nest (this cell was at the back of the nest, against the wall, so one side was open, but when the nest was returned to its position against the wall no mutilation was apparent to confuse the owner), and placed them in the new cell. She soon returned and set about promptly to remove these six spiders one by one and either dropped them after a flight of a few inches from the nest or carried them quite outside the barn.

Apparently she had had enough of this cell, for after a few minutes she flew in with a pellet of mud and began to seal it up, empty.

*Exp. 4.* A Pelopoeus mother was busily engaged in stocking her new cell. I plundered the nest of a blue wasp near by and placed six spiders from it in the new cell. The owner returned with a spider of her own, placed it in the cell on top of the stolen booty, pushed the whole in with her head and rammed it down about six times as though it were all her own, then flew out, returning almost at once with a pellet of mud with which she sealed the cell, and reinforced it with four or five more such balls. All this she did with an air of peace and satisfaction in work well done.

If some females can by some sense detect the spiders which have been caught and paralyzed by another of her kind, and express such resentment toward their presence, how much more strange it is that this one does not seem to be aware that part of her prey had been handled by a foreign species entirely, besides myself, or if she does know it, she cares not a whit.

*Exp. 5.* Next I tried a new form of interference, placing three spiders in a *Pelopoeus* cell which was only in course of construction, being but one-fourth completed. So it was not at all surprising that the wasp, after a little commotion, promptly emptied this and proceeded with her masonry.

*Exp. 6.* A blue wasp had completed her cell and placed her first spider there. I removed it, filled the entire cell with spiders from other nests and replaced her own spider in the front of the cell so that she would see her own prey when she returned. However, in handling the contents, I broke out a small piece of the wall at the opening. When I returned in a half hour I found that the cell had been emptied and deserted by the mother. Why did she go to the trouble of emptying it if she meant only to desert it?

*Exp. 7.* A new *Pelopoeus* cell appeared complete, but was still empty. The insect brought a load of mud, but used it to reinforce the nest, then she went all the way into the empty cell, and remained there for four minutes, only her tarsi protruding. What may have been her business during this performance we could not determine. When she had gone, thirteen spiders (one with a small egg attached) from another nest were placed in the cell. Upon the second and third trips she also walked over her nest and deposited the mud on the outside to reinforce it; she did not enter the cell, and I did not see her even look inside, but when she again came she used the load of mud to close the cell, then another and another until the seal was firm, just as though all were normal. Whether she detected the ample supply of spiders and closed the cell on that account, or whether she would have sealed it empty, had we not filled it for her, we could not determine.

*Exp. 8.* A *Pelopoeus* cell was finished and quite ready for use, but the larder was not yet stocked, so I filled it with spiders from another nest. The mother wasp returned with a fresh spider, started to enter the nest but retreated and flew out of the window, taking her burden with her. She returned empty-handed and carried out the intruders one by one. After the cell had been empty for a half hour, I again placed eleven spiders in it. The next morning when I arrived to examine this cell I found it had again been emptied.

*Exp. 9.* A Pelopoeus mother was carrying in spiders to fill the twelfth cell of a handsome nest, but had not gone far with the work when I added fourteen from the nest of another of the same species. The wasp returned and at once emptied the cell of my spiders and her own as well, and quietly stood guard over the cell for fifteen minutes with an air of indecision, and then flew away and was not seen again.

*Exp. 10.* A one-celled Pelopoeus nest was built under a piece of bark on a log beam in the old barn. I carefully removed this bark, filled the cell with borrowed spiders and replaced it. When the wasp returned she had great difficulty in finding the nest. After finally locating it she paused only a moment and dashed away, and returning removed the spiders one by one. Since the position of the nest was disturbed in gaining access to it, I should have been surprised if she had not resented the intrusion, although I cannot understand what caused her great confusion in locating the nest when the alterations in the locality were imperceptible to me.

*Exp. 11.* A solitary cell contained five spiders when I added six more from another nest. The wasp returned empty, put her head into the cell and worked energetically for three minutes, either inspecting or packing them together or laying her egg. Out she came at last and dashed away, but without a spider; almost immediately she returned with her plaster and sealed up the cell.

When she had gone, I broke the seal and removed part of the spiders which she and I had together supplied. She soon returned with another pellet of mud for the seal, but when she found it broken she alertly poked her head in, hastily withdrew and flew away with the mud. After that she made four trips from the nest, each time carrying out a spider which I had failed to remove, but these four were of those which she personally had put in. Then for ten minutes she thoroughly examined the inside and outside of the cell, going in and out many times, apparently in an earnest attempt to discover the cause of the mysterious trouble. When I returned at four p. m. I found her again filling this cell with spiders.

During her absence I again meddled, inserting twelve spiders from another nest. Returning she brought a spider which she

crammed into the cell with the others and departed. After ten minutes, however, she came buzzing back as if possessed of a new idea, and commenced to empty the cell. First she took out her own fine new one and threw it away, and returned repeatedly until the cell was again empty. She then remained on the nest, holding watch for thirty minutes, as if resolutely waiting to catch the hoodoo. When she left I expected her to refill the nest with spiders of her own capture, but instead she brought a load of mud and, to my amazement, spread it in a thin layer on the inside of the cell, as though the very walls were polluted, or else all of the trouble were due to its inadequacy. So, for the first time, I saw a wasp adding mud to the inside walls of a cell after she had once deemed it finished.

The next day, August 17, at three p. m., she was still occasionally coming to the cell with an air of angry suspicion and uncertainty, but otherwise it was in the same empty condition that I had left it. Unfortunately I was obliged to leave on the evening train, so I never knew what she finally decided to do.

*Exp. 12.* At six o'clock one August evening I filled a new one-celled *Pelopoeus* nest with spiders from another nest during the absence of its owner. I was called away and could observe it no further until the next day, August 17, when I found the cell sealed. I opened it and found that my intruders were gone and in their stead were two other spiders. The mother had evidently begun to fill the cell after having thrown out my spiders but had stopped with only two and sealed the cell without having even deposited her egg.

*Exp. 13.* A certain nest of a *Pelopoeus* was almost completed when I filled it with spiders from another nest. The proprietress returned with another load of mud to add another ring. When she saw the spiders she withdrew her head with a start, as though greatly shocked. Again she inquiringly put in her head, with a like result. She then went away in bewilderment and returned six times, but each time sought the nest at a spot two feet distant. Sometimes she would walk toward the nest, but always with the manner of one seeking for something lost.

After three days the cell was still in the same condition as I had left it; the wasp never finished it. I think that she firmly



believed that her nest was lost, and that the one to which she came again and again was the nest of another which had been filled with spiders.

*Exp. 14.* At 10:20 a new cell, the fifth on this nest, was commenced, and in just one hour and a half the new compartment was completed and ready to be filled and sealed. At this point I came forward with unasked aid and placed therein fourteen spiders from another nest. The wasp returned with a load of mud, no doubt to put on the finishing ring, but when she saw the spiders she showed not the least surprise or concern, but proceeded to seal the cell with the pellet she had brought. Then she brought another and another and added it to the closing in the normal manner, showing almost human standards of conduct in being satisfied in doing the thing most convenient at hand which gives the appearance of work well done, and glad of the opportunity easily to forget that she had quite overlooked the principal duty of her life. She seemed to give no serious thought to the presence of the spiders, nor did she make an effort to compress them nor show any concern for depositing her egg. The sight or scent of the spiders seemed to afford sufficient stimulus to cause her to seal the cell. Perhaps the presence of the mud already in her mandibles lent strength to the stimulus for this particular action.

At four o'clock that afternoon I found that this industrious mother had made another cell and was finishing off what I thought must be the last ring. When she flew out I placed six spiders in the cell and had not time to insert more when she returned with another load of mud. She got a glimpse of the spiders, which in this case only half filled the cell, and almost immediately flew out with the pellet. She threw away her mud and came hurrying back, peered into the cell and then bustled out again. She came back to the cell bent on her course of action, got a spider and carried it out. I then hurried to completely fill the cell by adding ten more spiders. But her zeal for righting wrongs was now aroused, and even this was no inducement to seal it up, for she carried them all out one by one.

*Exp. 15.* The new cell on this nest was just completed but as yet contained no food supplies, so I placed in it eight fresh spiders taken from another nest. The mother wasp returned with a load of mud and alighted on the nest, but from her be-

havior I judge that she suspected that it was not hers, for she arose on the wing and flew in wide circles and returned. This she did three times, the last time making a good many smaller circles. Through all of this confused search she carried her pellet. By this time she seemed fully convinced that this was her home, but that something was wrong. So she dropped her ball of mud out at the window, returned in a direct line to the nest, and began with a very positive air to carry out the spiders one by one, throwing them away until all were gone.

*Exp. 16.* A wasp was discovered putting the first layer on the closure of her cell. I removed this and also part of the spiders, all of her own capture. The wasp came in with more mud; hummed a little in anxious concern and flew out with her load. She returned shortly, however, and again sealed the cell. Again I opened it and inserted other spiders from another nest. She came back and saw the opening, poked her head into it enquiringly and proceeded to plaster it up. For the third time I broke the cell, but she seemed inclined to repair it as long as I would continue to damage it.

*Exp. 17.* A wasp had packed her cell nicely and already sealed it with two layers of clay. I carefully removed the covering and part of the spiders. The wasp returned with the next load of mud, hesitated only a little and spread it in its proper place and was off again. Again I opened it and this time inserted four foreign spiders. In due time the mother returned and again plastered the opening as if nothing had happened and departed. Bent on commanding her attention I broke the seal for the third time and placed a larva of *Pelopoeus* in the doorway, half protruding, so she could not seal the compartment without removing it. By the time she arrived with a pellet this larva had worked itself out of the cell, so she spread the mud as usual over the cell. When she had again gone I tried another very large larva in the same way. The mother wasp returned, made no attempt to remove the larva, or in fact displayed no concern for its presence, but spread the mud around it as it lay half protruding from the cell, often severely jarring it as she worked, plastering her mud to the sides of the larva as though it were a part of her wall, and thus again sealing in this silly fashion her cell.

*Exp. 18.* To a *Pelopoeus* cell containing a few spiders I

added five from another nest. The wasp returned, carrying another spider which she crammed into the cell, while with her head she condensed the whole mass. In so doing she somehow dislodged one and it fell into the spiderweb below; she alertly recovered it, crammed it into the cell with precision and continued to pack the mass together for about five minutes, then flew out and brought one more spider which she deposited, almost filling the compartment.

When she had gone again I forced five additional spiders into the cell; after a half hour she returned with another capture which she also forced in with great effort. It seemed that she had a fairly definite idea how many spiders were required, and bring them she must and would, regardless of unsolicited aid. In this she differed from other individuals of her species, in whom the sight alone of few or many spiders in the cell was sufficient stimulus to induce the sealing process.

But upon her next return she brought a load of mud and closed the cell. When she was gone I opened it and removed one-third of the spiders. The next load of mud was used in precisely the same way; absolutely no attention was paid to the broken cell or the missing spiders. Again I removed the seal and all of the spiders in order more forcibly to impress upon her the seriousness of the injury. I accidentally broke a small piece out of the wall of the cell at the opening. The wasp returned, spread her mud over the opening, leaving the broken part untouched and quite ignoring the emptiness of the nest or the traces of vandalism. She discharged her duty always with a mechanical faithfulness; she seemed, nevertheless, exact—three loads of mud are usually required to seal a cell, and three loads she brought and applied properly before finally leaving the nest.

*Exp. 19.* When I arrived upon the scene the fourth cell of a *Pelopoeus* nest was half filled with spiders. Not having other spiders at hand, I placed a pupal case containing a pupa of the same species in her cell so that no part protruded. When I returned two hours later the cell was sealed and a fifth cell of the nest half completed. I had to break open the cell to see if the pupa had been removed. The cell was quite empty, but the new item of interest was that at six the next morning I

found this damaged cell repaired and the fifth cell still in its half finished condition. This was the first case in my experience of a wasp going back and giving attention to a previously finished cell after a subsequent one had been begun.

#### CONCLUSIONS

When we attempt, finally, to formulate any generalizations concerning the behavior or psychology of these insects, there seems to be only one principle which can be relied upon to hold good in all cases, viz.: that the madam will do as she pleases. Cases of similar conduct under homologous circumstances can hardly be found. Yet we cannot regard the behavior of the wasp as indifferent or accidental when we see her very positive air in taking action, and her usual determination and persistence in pursuing it when she has decided upon her course of action. It may seem to some readers that these observations are too artificial or experimental in nature and too limited in number to justify a conclusion so vague. To be sure all these experiments threw the insects under abnormal and unnatural conditions, so we need not marvel, perhaps, that no two behaved alike under provocation. But the detailed examination of many hundreds of completed nests<sup>2</sup> shows that in normal, free life these wasps commit blunders or follow disastrous whims in a large proportion of their cells; sealing them stark empty or with only a fraction of the food necessary for the young one, or providing abundant supplies and omitting the egg, or other blunders which would defeat the whole purpose of the wonderful instinct of nest-building.

In answer to the question suggested in the title we can only say that in most of the cases where the spiders were disturbed the owner was quick to detect it and frequently resented it. But since in her anger she often threw away part or all of her own prey we cannot determine whether or not she recognized her own, or merely regarded with alarm any meddling about her home. Likewise in those cases wherein she accepted our proffered aid she did so with such outward indifference, taking it all as a matter-of-course after the manner of those accustomed to welcoming charity, that we could not discern whether or not she was the wiser.

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<sup>2</sup>The data are in course of preparation for publication later.

## OBSERVATIONS ON THE BEHAVIOR OF BUTTERFLIES

CHARLES W. HARGITT

The following observations have been made at various times during several years as opportunity has afforded, and with little thought that they might ever be offered for publication. Looking them over recently it has seemed that there might be a few sidelights which would have some interest to students of behavior, and with this in mind they have been written out quite briefly as an incidental contribution to a subject of vast interest and importance.

The lepidoptera have been for many years a favorite group among students of tropisms. The familiar phenomenon of the moth fluttering in the candle flame at night has long ago passed into a proverb. It is only within recent times that observations upon butterflies, and also upon many larvae of these forms, have come in for critical study and attempted explanation. It is no part of the present purpose to attempt any review of the subject, though a few references can not be avoided in discussing the facts to be reported. While the earlier observations and deductions of Loeb, Davenport, Graber, Radl and others have been of value, and have stimulated greatly the interest in the subject, it remained for later students to undertake to study with accuracy and critical control the factors involved in the behavior. To the writer it has seemed that the work of Radl and Parker have been noteworthy in this respect. It was the graphic account by the latter on "The Phototropism of the Mourning-cloak Butterfly, *Vanessa Antiopa* Linn.," which prompted the observations herein submitted. In most respects they will be seen to confirm the facts cited by Parker, and but for a few features which apparently differ in certain fundamentals, there would have been small occasion for giving them publicity.

Let me say at the outset that my observations were made wholly in the open, that is, in the natural habitats of the organisms, no attempt being made to put specimens under artificial



control. In earlier papers I have expressed the conviction that much of such artificial work has been far from convincing, and some of it actually mischievous. It may be probable that some of this failure attaches to study of lepidopteran behavior !

My observations began with the study of *Vanessa antiopa*, and were chiefly directed to that species, but several other species also came in for a share of attention. The following points will be emphasized: (1) Marked individual differences of behavior under apparently identical conditions; (2) differences at various times of day, and various days; (3) marked sense of locality and adherence thereto; (4) lack of evidence of any sex adaptation in the color markings as related to behavior.

My observations confirm those of Parker, (1) as to the dominance of "chemotropic response to food;" (2) the general negative phototropism in strong sunlight; (3) general indifference of butterfly to shadow stimuli except in the head region.

My first notes on the behavior of *Vanessa* were made on a bright, warm day, the 25th of March. The first two specimens found were very wary and difficult to approach, but two other specimens proved less wild, and allowed easy approach and close observation and experiment. Several others were found later which also allowed approach and similar observation. One of these specimens alighted on an exposed snow-bank, oriented in the usual manner, seemingly not at all disturbed by the icy substratum on which it rested. In all some twenty careful observations were made in relation to the particular orienting behavior, and in general conformed fairly constantly to the results obtained by Parker. As a basis on which to estimate the degree of exactness of the orientation I regarded any reaction which did not vary more than ten degrees from the precise line of the sun's rays as conforming to the law, while anything beyond this was regarded as a departure, or failure to conform to the law. This is, of course, a purely arbitrary way of estimating the reaction, but unless one insists on mechanical precision in every case (a method which might be demanded), it seems as good as one might propose. In the first series, just given, the majority clearly behaved in conformity with expectation, but a number as clearly fell outside such expectation. In this connection were noted facts which clearly illustrate the individual difference of behavior, e.g., the differing susceptibility

to alarm. Shall one use the term *alarm* in referring to such behavior? If the organism is pure mechanism the use of such terms is of course inadmissible. But if we are dealing with an *organism* in the true sense, then no other term is more pertinent and significant. That this is the real state of the case one is forced to believe in that the same specimen will exhibit the same differences of behavior at different times, acquiring keener sense of alarm from *experience*. Again, the behavior varies on different days. On some days they seem to seek the ground predominantly, while on others they "come to earth" seldom and for brief periods. This was noted so often as to leave no doubt as to the fact. That it may not be due to difference of light intensity is evident in that the same differences will be observable in different specimens at the same time and therefore under identical light intensity. For example, it was found to be true in the behavior shown at ten o'clock and that at two o'clock the same day, and under indistinguishable conditions of light, though appreciable differences of temperature were evident, and it is not impossible that this may be a factor in the matter. Exactly these facts were illustrated by my next field trip four days later, on March 29th. In the forenoon specimens were extremely wary and difficult of approach, and the behavior was erratic and uncertain. During the afternoon of the same day, accompanied by an assistant, it was like encountering a different species. Specimens were "tame," observation was easy, and any number of tests could be made with precision.

My next observations were made just a month later, with a clear, warm day. At least seventy-five observations were made during the afternoon, including numerous shadow tests. While in the majority of cases there was a more or less evident orienting response, as before a considerable number varied greatly as to the precision of reaction. It was not unusual to have a specimen alight at an angle of 90 degrees from the parallel of the rays of the sun, and occasionally a specimen would come to rest directly facing the sun and remain thus. A single specimen was found which proved very approachable and responded very readily to tests, and on it were made about forty direct tests, of which thirty showed orienting reactions more or less precise. The other ten reactions showed considerable more

deviation, sometimes as much as 45 degrees. In course of these observations it was found that the position of the support upon which the specimen came to rest often had a modifying effect as to its final position. That is, if the specimen alighted upon a twig which was slightly out of the line of the rays of sunlight it conformed to the axis of support instead of that of the rays. In one case the specimen alighted upon a dry leaf stem with the head upward, and about 30 degrees from the parallel of the sun's rays. This effect of the influence of the supporting basis was frequently observed in later cases and I think affords an important factor to be taken into account in such cases. Evidently here was a stimulus which served to modify in a very appreciable degree the character of the behavior. On this specimen a number of experiments were made by means of shadows cast upon the body. In some cases these were produced by means of the hand, sometimes by using one's hat, and in some cases by a cane which might be made to cast a definite and localized shadow. Under total shadow the specimen usually showed reaction in from 5-10 seconds, and within 15 seconds would fly into the light (occasionally the movement would be by crawling). Under partial shadows, i.e., a part of the body in shadow, the reaction was less prompt, from 15-20 seconds. As in the total shadows, the reaction might involve flight, or a mere creeping forward or sidewise, as the case required. The response was in general more prompt with the shadow on the anterior of the body and head and slowest when the posterior part was under shadow, which would seem to imply the relation of sight in the reaction, though not wholly.

On May 27th a series of observations were made under very favorable conditions, the specimens being easily approachable and seldom taking fright or leaving the place. The records of the day included fifty observations, and of these hardly more than half of the photic reactions came within the 10 degrees arbitrarily set as a sort of limit for precise orientation. Variations from 10-30 degrees were very common and in a few cases the variation was definitely 90 degrees from the line of the rays. Experiments with shadows showed some interesting features not noted before. In a few cases total shadow produced no reaction at all; but in most cases there was response within about the limits already noted. In some cases a specimen

would give signs of reaction by becoming restless, edging side-wise, forward, and finally in flight, alighting in open sun. One of the unusual phases intimated above was noted upon two specimens, namely, while resting and oriented in about normal manner, with wings spread wide and flat, they would slowly close them over the dorsum. While in this pose, if a shadow were cast upon the specimen, its reaction would be an immediate spreading of the wings. Upon removing the shadow the wings would again close over the back; and repeating the shadow the same reaction would occur. This experiment was repeated upon one specimen seven times at intervals of from 15-20 seconds.

To test whether this particular form of reaction was due to sudden visual reflex the interposition of the shadows was made so gradually as to render any such reaction rather improbable, or again by sudden thrusting of the shadow upon the body to induce such reflex. But it was not evident that the reaction was wholly visual.

Another feature of the observations today was the fact that no selection was apparent upon the part of specimens as to the place of coming to rest. For example, they frequently came to rest on the open, spreading leaves of the mandrake, leaflets of cohosh, grass blades, etc., and in some cases nestling down among grasses, utterly indifferent to the hazy shadows of such positions. In other cases they would alight on dead stumps, naked limbs, flat stones, etc., and almost invariably with the head directed upward, sometimes at an angle of 20-30 degrees from level of the ground. In only one case in all the observations was a specimen seen to alight upon a tree trunk.

*Sense of locality.* It was frequently noted that a given specimen showed some sense of particular locality. For example, it was often observed that a specimen at rest and oriented in a given place would arise in chase of a passing specimen and after a buffeting flight together for some distance the first specimen would return and alight in the same spot from which it had taken flight. This was seen so many times that there hardly seems doubt of the fact that it reveals a sense of locality almost as marked as by such insects as bees. Reference will be made to this matter in a later section in connection with the question of sex attraction.

My next observations of importance took place at Woods



Hole in July and early August and had to do with another butterfly, namely, *Argynnis idalia*, a species rather common in the locality. The specimens are of the field habit rather distinctly and seek the open sunshine. Like Vanessa this butterfly orients itself in almost exactly the same manner. But their reaction is much less exact than that of Vanessa. And when tested as to the effect of shadows to my surprise they showed hardly any reaction. In a number of cases the shadow of a hat interposed and withdrawn as many as a dozen times at intervals of from a few seconds to as much as a minute produced no response. These experiments were repeated on other specimens and with the same results. When put to flight a specimen soon comes to rest in the same general attitude as before. The color of this insect is much more striking than is that of Vanessa, and if this were a means of attracting mates, as Parker has suggested, then it might be expected to be much more effective. But I have never, in either case, seen the slightest evidence that this is in any sense such a device, nor that the special pose and orientation has anything to do with such ends. As with Vanessa specimens of *Argynnis* show great variation as to ease of approach, some being exceedingly wary and wild, others tame and easily studied. Such is the case with almost all the species studied. Whether this may be due to greater or less visual sensibility or simply to more or less alarm in the presence of strange objects may be matter of doubt.

My next observations which add anything essential to the facts concerned were made in September of the following year in the fields adjacent to Syracuse. I had at this time opportunity to observe several species in addition to Vanessa antiopa, among them a species of Papilio, probably *asterias*, and another which I was not able to identify. As compared with Vanessa the behavior of Papilio showed several rather marked differences. In the first place there was no indication of phototropism of any sort. On coming to rest upon the ground there was not the slightest disposition to orient itself with reference to the sun's rays. On the other hand there was orientation with respect to direction of wind, the creature seeking to face the wind thus probably taking the position of least resistance to the wind which was rather strong at times in the exposed field. Continued observation showed that this behavior was not merely



incidental, but definite and purposeful. In flight there was no apparent reaction of the sort, the specimen flying as much directly against, as with the wind currents. In repose the specimen showed the same pose of wings as *Vanessa*, a fact which was rather unusual for a *Papilio*, whose attitude is usually quite the opposite, namely, to rest with closed wings. The response to shadows was essentially the same as *Vanessa*, though less marked. At times a specimen would remain at rest indefinitely under a shadow, but the opposite reaction was predominant.

The other species behaved in much the same manner as *Vanessa*, but its photic reactions were much less marked. Its behavior in relation to other species in flight was exactly as in *Vanessa* and other species already mentioned. This chasing and buffeting behavior appears to be related to the mating instinct, but it was not possible to distinguish that it ever resulted in actual copulation. Further reference to this will be made in another section.

Numerous other observations were made, all giving about the same results, and all revealing more or less clearly the individuality to which attention was directed in the introductory section. It was quite evident that in this behavior one has to recognize that reactions are not simple, nor are they definite and stereotyped as might be expected on the assumption of the so-called laws of phototropism. As Parker has well said, "this problem, at least so far as butterflies are concerned, is much more complex than was suspected by either Loeb or Davenport. The reactions of *Vanessa antiopa* to light cannot be satisfactorily considered without dealing with the influence of heat, food, and gravity." I think it may also be added, without recognizing the influence of an individuality characteristic of all higher organisms.

*Sex as a Factor in Behavior.* Parker has emphasized the probable relation of certain phases of the behavior, especially that of the peculiar pose of the wings and photic orientation, to the problem of "bringing the sexes together during the breeding season." This view has received no confirmation in my observations. At no time have I ever observed a specimen in flight hover about one in repose as if attracted toward it. Invariably the first sign of recognition has been by the resting specimen, which often appeared to be on watch for the passing

of one of its kind. This was true of all the species observed. I have often noted the fact that any passing object in flight over one of these "watching" specimens, such as a bird, or a bumble bee, would have the effect of stimulating the same sort of chase as would be the case with a similar passage of one of its own species. I have seen a *Vanessa* chase a *Papilio*, or a *Pieris*, or, indeed, almost any similar object.

That there is a sex factor involved in this peculiar behavior I think altogether probable. But that the color pattern, or the wing pose of the specimen has any such function seems extremely improbable. A further fact which tends to support this view is that the behavior in question does not seem to be limited at all to the breeding season. It is quite as marked in July as in April or May. Indeed, so far as my observations go, there is nothing to show that this behavior differs materially at any time during the active life of the butterfly.

Still a further point may be noted as bearing on the question, namely, it does not seem to me that the color pattern of the wings of *Vanessa* serve to make it a specially conspicuous object when in this orienting pose. If a perfectly bare, white or grayish position were always sought this might be the case to some extent, but the habit of *Vanessa* rather dominantly in or about wood lots, where many and varied lights and shadows mingle, would tend to render these markings rather protective than otherwise. I have personally demonstrated this on many occasions when following up a specimen for closer study. Even when marking down a specimen as it came to rest and hastening forward with the eye upon the spot, it often was impossible to see the thing until it took flight, so intimately had its markings been blended with its surroundings.

These facts and the further fact that the behavior is not peculiar to *Vanessa*, but is shared by a considerable number of species, some of which are very brilliantly colored, afford a strong evidence in disproof of the view proposed by Parker touching its function as a sex factor.

## NOTES

### THE ROLE OF THE EXPERIMENTER IN COMPARATIVE PSYCHOLOGY

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In Comparative Psychology attention has recently been concentrated upon the control of the experimental situation to the neglect of two other aspects of our task which are equally worthy of study,—namely, the management of the subject and the reliable recording of responses. Every psychological problem presents, if attacked experimentally, these three technical demands: first, such control of the objective situation as shall render it not only suitable for the solution of the particular problem, but at the same time, highly controllable and describable; second, such knowledge of the subject, human or infra-human, as shall enable the experimenter to avoid unnaturalness, or otherwise unnecessary ill-adjustment of subject to objective situation; and third, such provision for the recording of response as shall provide wholly reliable and sufficiently detailed descriptions of the subject's behavior.

By experience in working with various animals and with pathological human subjects, I am convinced of the urgent need of attention to our methods of recording reactions. We, at present, allow the experimenter too great range and place upon him over-great responsibility. As observer, he is liable both to influence the subject in his attempts to get data of reaction and, in turn, to be influenced, in his descriptions of what he sees, by his unescapable tendencies to interpret. Quite evidently, the ideal experiment is one in which the subject provides us a detailed photographic record (or other form of graphic record) of its response. It is the writer's belief that we should make systematic and persistent attempts to develop recording devices which shall free us from the observational imperfections of the experimenter.

This means that our apparatus for use in Comparative Psychology must be largely automatic or self-controlling over considerable periods of time, not only with respect to the objective situation or setting in which the subject reacts, but also with respect to the recording of the several important aspects of response. We should devise types of recording mechanism which shall either operate automatically or be operated by the subject rather than by the experimenter. This would mean not the elimination of the observer but the freeing of his attention for those aspects of the total experiment which most urgently demand control.

As an example of a practical recording device, I may mention that of the Hamilton Quadruple Choice Apparatus which, in its latest improved form (thus far undescribed) permits the experimenter to confront his subject with a certain situation and then leave that subject to work out a series of problems, its behavior in connection with which is the whole accurately recorded by a system of markers, electrically actuated.